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ICAM CONCEPTUAL DESIGN FOR COMPUTER-INTEGRATED MANUFACTURING

Volume I
Project Overview and Technical Summary
Final Technical Report (FTR)

LTV Aerospace and Defense Company
Vought Aero Products Division
Post Office Box 225907
Dallas, Texas 75265

June 1984

Final Technical Report for Period
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Prepared for:

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29 June 1984

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Richard R. Preston

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September 3, 1984
DATE

FOR THE COMMANDER:

N G Tupper

NATHAN G. TUPPER
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This Final Technical Report (FTR) covers the work performed on U. S. Air Force Contract F33615-81-C-5119, Project Priority 1105, entitled "ICAM Conceptual Design for Computer Integrated Manufacturing." This Technical Report presents an overview and technical summary of the overall project, its results and discusses the rationale for the direction of the program.

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Volume II	**Establishment of the Factory of the Future Conceptual Framework**	
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	Volume IV, Part 3	System Environment Document (SED), SED110513000, 31 August 1983
	Volume IV, Part 4	System Requirements Document (SRD), SRD110513000, 24 September 1982
	Volume IV, Part 5	Architecture for Product Assurance, TTD110513000, 10 January 1984
	Volume IV, Part 6	Quality Assurance Program Management Standard Recommendations (ISP), ISP110513000, 18 August 1982
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FOREWORD

This Final Technical Report (FTR), was developed under Air Force Contract #F33615-81-C-5119, Project Priority 1105, entitled "ICAM Conceptual Design for Computer Integrated Manufacturing." This contract was sponsored by the Computer Integrated Manufacturing Branch, Manufacturing Technology Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, 45433. This project was administered under the technical direction of Captain Richard R. Preston.

This document, Volume I, of the Final Technical Report, contains the Project Overview and Technical Summary for the ICAM Conceptual Design for Computer Integrated Manufacturing Project.

The results of this project have been achieved by a coalition of companies organized and managed under the leadership of the prime contractor, Vought Corporation, with Mr. Don L. Norwood providing primary overall contract leadership and management responsibility (TASK A). Other Task leaders were:

1. Mr. Robert L. Moraski, Vought Corporation, responsible for leadership and management of the Factory of the Future Conceptual Framework Thrust (TASK B).

2. Mr. Frank E. Sullivan, Northrop Corporation, responsible for leadership and management of the Integrated Composites Center Conceptual and Preliminary Designs (TASK C and TASK E).

3. Mr. Robert H. Wettach, General Electric Company, responsible for leadership and management of the Quality Assurance Modeling and Analysis Thrust (TASK D).

The other major participating companies of the coalition were:

- o D. Appleton Company, Inc. (DACOM)
- o General Dynamics/Fort Worth
- o Hughes Aircraft Company
- o Illinois Institute of Technology Research Institute
- o SofTech, Inc.

In addition to the major coalition participants, the following companies and organizations served as reviewing participants on one or more project thrusts::

- o Battelle Columbus Laboratories
- o Baughman Consulting
- o Bell Helicopter
- o Bendix Corporation
- o Boeing Aerospace Company
- o Boeing Commercial Airplane Co.
- o Boeing Computer Services Company Division
- o Boeing Military Airplane Co.
- o Cincinnati Milacron Incorporated
- o Douglas Aircraft
- o Fairchild Republic Co.
- o General Electric:
  - Aerospace Electronic Systems, Utica
  - Aircraft Engine, Evendale
  - Simulation and Control Systems, Daytona Beach
  - Ordnance, Pittsfield
  - Military Electronic Systems, Syracuse
  - Re-entry Systems, Philadelphia
  - Aerospace Control Systems Binghamton
- o Goldsworthy Engineering
- o Grumman Aerospace Corporation
- o Honeywell, Inc.
- o HQ Aeronautical Systems Division
- o HQ Air Force Contract Management
- o HQ Armament Division (AFSC)
- o HQ Arnold Engineering and Development
- o HQ Ballistic Missile Office (AFSC)
- o HQ Defense Logistics Agency
- o HQ Naval Air System Command
- o HQ Space Division
- o HQ-NASA
- o Hughes Helicopter
- o Ingersoll Milling Machine Co.
- o Lockheed Georgia Company
- o Lear Siegler, Inc.
- o Lockheed Missiles and Space Co.
- o Martin Marietta
- o McDonnell Aircraft
- o NASA
- o Office of the Undersecretary of Defense
- o Research Triangle Institute
- o Rockwell International
- o Sikorsky Aircraft
- o TRW, Inc.
- o Texas A&M University
- o Texas Instruments Incorporated
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- o United Technologies Corp.

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INTRODUCTION

SECTION 1.0

INTRODUCTION

1.1 PROJECT 1105 OBJECTIVES

There were three major objectives to be accomplished on ~~the~~ this "Conceptual Design for Computer Integrated Manufacturing" contract:

(1) The Factory of the Future (FoF) Conceptual Framework (Task B) had three specific overall objectives:

- o A. To develop a strategy to achieve a computer-integrated framework concept that integrates all major activites (e.g., Design, Marketing, QA/QC, Product Support, Manufacturing Planning, etc.);
- o B. To establish an overall Conceptual Framework that will describe these integrated activities; and
- o C. To create an aerospace enterprise framework structure that serves as a baseline for computer-integrated manufacturing (CIM) initiatives through the year 1995.

(2) The Integrated Composites Center (Tasks C/E) had has its objective the acceleration and modernization of composites manufacturing operations. Task efforts were devoted to establishing preliminary designs and specifications for a computer aided composites manufacturing center that integrates all activities required to produce composite aircraft structures.

(3) In the Quality Assurance Modeling and Analysis (Task D) effort, the objective was to identify computer integrated technologies that would allow the aerospace industry to reduce product costs while maintaining traditionally high quality standards.

1.2 MAJOR PROJECT 1105 TASKS

The major tasks which were to be accomplished on this project are shown in Figure 1-1.

1.3 PROJECT APPROACH

All major task coalition teams of Project Priority 1105 pursued their objectives using the proven four phased ICAM Life-Cycle approach to systems development. This phased task approach of study, design, and implementation has been successfully used to implement specific technologies in firms throughout the country. The USAF ICAM IDEF (I for ICAM, DEF for definition) modeling methodologies for function (IDEFØ) and information (IDEF1) were

The following tasks shall be accomplished:

Task A - Establishment of the Master Plan and Schedule (paragraph 4.1).

Task B - Establishment of the Factory of the Future Conceptual Framework (paragraph 4.2). (Option 1)

Task C - Establishment of the Integrated Composites Center Requirements Definition and Conceptual Design (paragraph 4.3).

Task D - Establishment of the "AS IS" Architecture of QA/QC Functions (paragraph 4.4.2), Establishment of the ICAM Quality Assurance Manual (paragraph 4.4.3) and a Product Assurance Program Standard (paragraph 4.4.4).

Task E - Establishment of the Integrated Composites Center Preliminary Design and System Specification Document (paragraph 4.3.8). (Option 2)

Figure 1-1. Technical Requirements/Tasks

used by all three tasks of this project. Figure 1-2 is an IDEFØ model depic.ing the function relationships that existed been the major project tasks. Of key importance is the incorporation of other than ICAM manufacturing data and the feedbacks from Task C (the Integrated Composites Center Conceptual Design) and Task D (the QA/QC effort) to Task B (the Factory of the Future Framework).

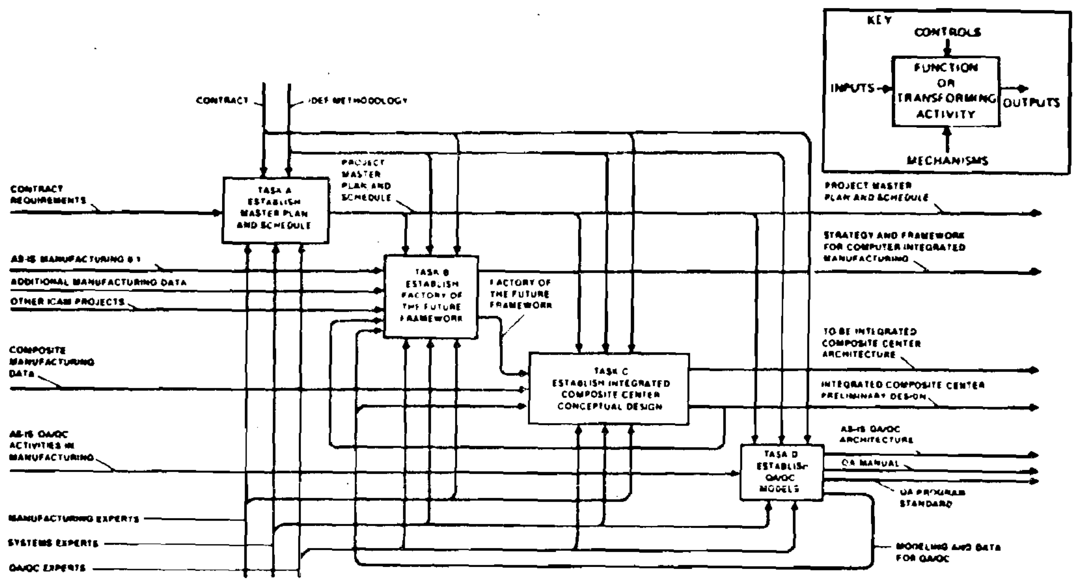

Figure 1-2. IDEFØ Model of Project 1105

1.4 PROJECT TIME SPAN CHART

A time span chart is shown in Figure 1-3 which establishes when the major project tasks/options are to be accomplished.

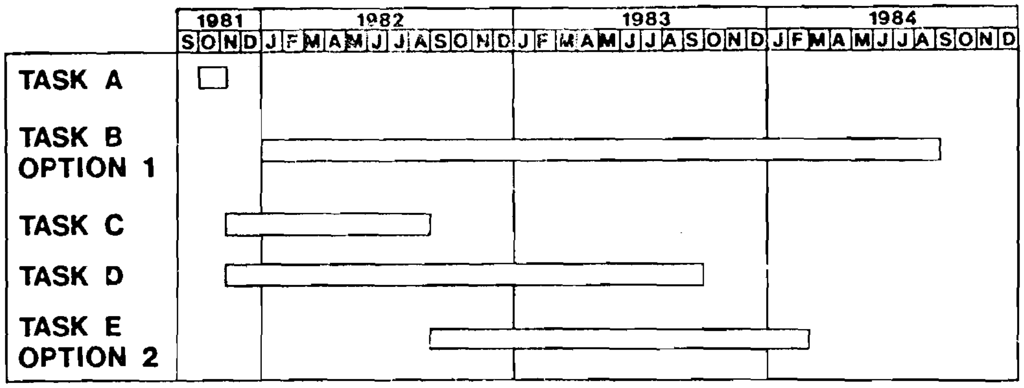

Figure 1-3. Time Span Chart

1.5 LIST OF PROJECT 1105 TASKS AND SUBTASKS

Because of the complexity of project 1105, a complete list of the project technical requirements and tasks are shown in Table 1-1 as they appear in the contract Statement of Work (SOW).

1.6 INDUSTRY COALITION

The Vought-led coalition was a results-oriented team of manufacturing specialists with the diversity of skills and experience necessary to successfully accomplish the goals of the project. The team possessed demonstrated manufacturing and QA/QC expertise. During the course of the project, it proposed many innovative solutions to previously identified ICAM problems. The coalition also included an experienced group of technical consultants and advisors who complemented the resources of the major contractors. Figure 1-4 shows the coalition organization.

1.7 PROJECT 1105 CONTRACTOR/SUBCONTRACTOR RESPONSIBILITY

An overview of the entire coalition responsibilities an approach to Project 1105 is provided in Figure 1-5.

TABLE 1-1. LIST OF PROJECT 1105 TASKS AND SUBTASKS

4.0 TECHNICAL REQUIREMENT/TASKS

- **4.1 Phase I, Task A, Establish Master Plan and Schedule**
- **4.2 Phase II (Option 1), Task B, Factory of the Future Framework (FOF)**
  - 4.2.1 Scope the Technical Effort and Identify Needs
    - 4.2.1.1 Scope the Technical Effort
    - 4.2.1.2 Identify Needs
  - 4.2.2 Establish Improvement Concepts
    - 4.2.2.1 Evaluate Improvement Concepts from Existing Systems
    - 4.2.2.2 State-of-the-Art Investigation
    - 4.2.2.3 Document Systems Requirements
  - 4.2.3 Detail Factory of the Future Concepts
    - 4.2.3.1 Establish Factory of the Future System Specification
    - 4.2.3.2 Establish Factory of the Future Framework
    - 4.2.3.3 Analyze Factory Framework, Centers and Subsystems Interactions
    - 4.2.3.4 Economic Benefit Analysis
  - 4.2.4 Summarize Factory of the Future Results
- **4.3 Phase I Task C, Establish Integrated Composite Center Conceptual Requirements**
  - 4.3.1 Establish Integrated Composites Center Scope
  - 4.3.2 Complete Needs Analysis
  - 4.3.3 Complete Current Practice Understanding
  - 4.3.4 Formulate Improvement Concepts
  - 4.3.5 Define Integrated Composites Center System Concepts
  - 4.3.6 Produce "TO BE" Integrated Composites Center System Requirements Document
  - 4.3.7 Preliminary Design Subplan
  - 4.3.8 Phase III (Option 2), Produce Preliminary Design
    - 4.3.8.1 Refine and Detail Requirements
    - 4.3.8.2 Design Integrated Composite Center System
    - 4.3.8.3 Produce "TO BE" Integrated Composites Center Models
    - 4.3.8.4 Produce "TO BE" Integrated Composites Center System
    - 4.3.8.5 Conceptualize and Document Integrated Composites Center System Configuration
    - 4.3.8.6 Establish Integrated Composite Center System Test Plan
    - 4.3.8.7 Produce Configuration Item Identification
- **4.4 Phase I, Task D, Quality Assurance/Quality Control/Technical Requirements/Tasks**
  - 4.4.1 Establish QA/QC Project Plan and Schedule
  - 4.4.2 Understand the Problem Using the MFG 0, MFG 1, DES 0 and DES 1 Architecture
    - 4.4.2.1 Perform Needs Analysis
    - 4.4.2.2 Establish "AS IS" Environment
    - 4.4.2.3 Establish the "AS IS" Composite QA/QC Models
    - 4.4.2.4 Establish "AS IS" Architecture Interface
    - 4.4.2.5 Establish Improvement Concepts
  - 4.4.3 Establish QA/AC Manual
  - 4.4.4 Establish Product Assurance Program Standard

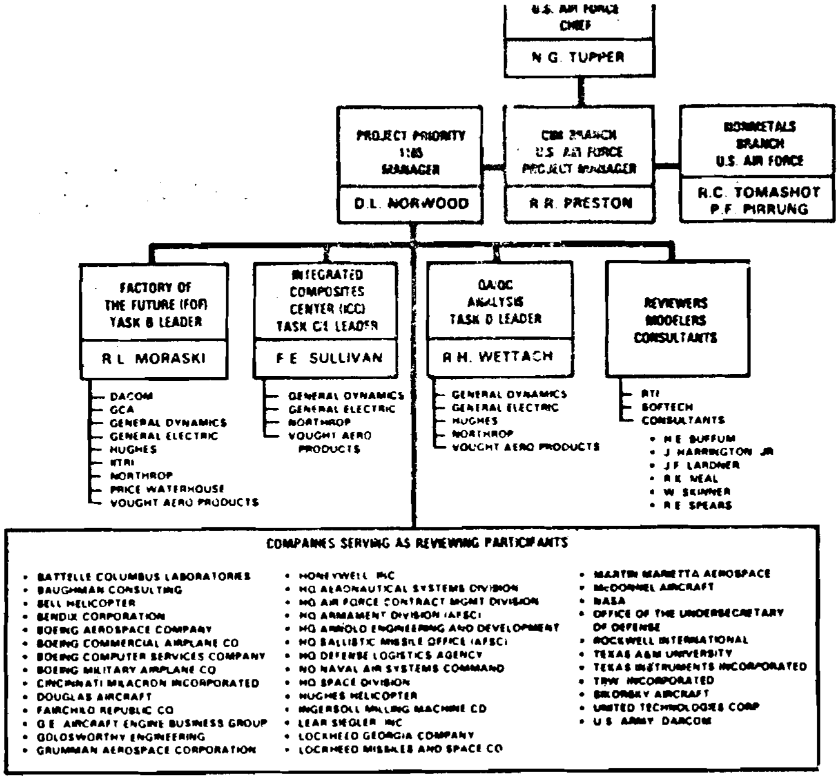

Figure 1.4. Project 1105 Organization Chart

WBS ITEMS	VOUGHT	NORTHROP	GE	GD/FW	HUGHES	IITRI	SOFTECH	DACOM
4.0 Technical Requirements Tasks								
4.1 Task A/Establish Master Plan and Schedule	X	S	S					
4.2 Task B/Establish Factory of the Future (FOF) Framework	X	S	S	S	S	S	R	S
4.3 Task C/Establish Integrated Composites Center Conceptual Design	X	X	S	S	S		R	R
4.4 Task D/Quality Assurance/Quality Cont ol/Technical Requirements/Tasks	X	S	X	S	R		R	R

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X - Responsible S - Support R - Review

Figure 1-5. Contractor/Subcontractor Responsibility for Project 1105

SECTION 2.0

EXECUTIVE SUMMARY

SECTION 2.0

EXECUTIVE SUMMARY

2.1 Establish Project Master Plan and Schedule (Task A)

The Project Master Plan and Master Schedule was finalized and implemented as a management tool and project roadmap in November 1981. The Project Master Plan described the project organization, assignment of responsibilities, management procedures and reporting requirements. The Master Plan was revised twice during the project duration.

The Project Master Plan and Master Schedule was instrumental in tracking and monitoring project progress; initiation of new tasks as well as verification and reporting activities involving project results.

2.2 Establish Factory of the Future Conceptual Framework (Task B)

Since its inception, the U.S. aerospace industry has established an unsurpassed record for developing high-performance quality weapon systems. In responding to the requirement for constantly improving product performance this industry established an enviable track record for developing and producing technically superior weapon systems. This response, in turn, led to the development of a "product performance at any cost" attitude.

Advanced materials and structure technologies have evolved and have been incorporated into new aerostructure designs to meet the demand for improved products. In adapting these new technologies, the aerospace industry has, essentially, continued to pursue the challenge to develop superior products by conducting business-as-usual.

This approach, coupled with economic constraints, spiralling production costs, and a nation-wide decline in productivity have significantly increased the costs of weapon systems over the last 15 years. As a result, this signals an end to the era where costs could be ignored for the sake of performance, even when dealing with systems on the cutting edge of technology.

It has now become clear that, as a nation, we may well be approaching a time when procurement costs could compromise our defense requirements. Weapon system costs are now being considered and evaluated equally with performance.

As one of the primary customers for U.S. aerospace products, the United States Air Force (USAF) became increasingly concerned with contemporary trends in this essential defense industry. With product costs isolated as the deciding factor in new weapon system procurement, the USAF reasoned that the technology development revolution, which had helped to escalate aircraft costs, could by the same token, be applied to reduce aircraft costs through the implementation of computer integrated manufacturing (CIM) systems. To this end, the USAF Integrated Computer Aided Manufacturing (ICAM) Program was initiated. The ICAM charter was focused on the identification and application of manufacturing technologies that offered productivity improvement, cost reduction and product quality enhancement.

The creation of an organized program (ICAM) for encouraging the U.S. aerospace industry to look beyond the business-as-usual approach of the 1950's for answers to improving cost and productivity has proven quite successful. Numerous ICAM projects have produced a host of information for improving aerospace manufacturing through the implementation of automation and computer technologies. These ICAM efforts have reversed the trend of increased production costs and declining productivity at the shop floor level.

These promising, though limited successes, of ICAM developed technology application coupled with the realization the weapon system cost increases extended beyond the shop floor suggested that a new way of thinking, a new way of doing business was necessary if our aerospace industry was to survive in the last decade of the 20th Century and succeed in the 21st Century. With this realization, ICAM established a far-reaching project comprised of tasks focused on identifying a new order, a new structure for the aerospace industry.

In an effort to capitalize on previous ICAM project results and to go beyond the limited successes attained with individual shop floor projects, ICAM Project Priority 1105 "Conceptual Design for Computer Integrated Manufacturing" was established. This project was scoped to analyze the total system of the aerospace enterprise and its operations; not just the shop floor and applicable manufacturing technologies. The challenge was to examine, dissect and assess the essential functional elements required to produce an aerospace product and develop a framework or guidelines for their integration! These elements included Design, Finance, Marketing, QA/QC, Manufacturing, Inventory Control and Product Support.

The resulting Conceptual Framework for a Factory of the Future (FoF) was to provide guidelines for the horizontal integration (between functional elements) of the aerospace enterprise and the vertical integration of the functional elements. To assure that the resulting conceptual Framework was complete, two supporting tasks (which in themselves were major contractual efforts) were incorporated into project 1105. These supporting tasks further defined two essential aerospace enterprise entities: composites structure manufacturing (Tasks C/E) and QA/QC (Task D); they will be discussed separately in the following sections of this Volume as well a in full detail in Volumes III and IV respectively.

To fulfill the aims of the expansive scope of this task to develop a Conceptual Framework for a FoF, three specific overall objectives were established and met. These objectives were:

- o To develop a strategy to achieve a computer-integrated framework concept that will integrate all major functional elements (e.g., Design, Finance, QA/QC, etc.)
- o To establish an overall Conceptual Framework that will describe these integrated activities
- o To create an aerospace enterprise framework structure that will serve as a baseline for CIM initiatives through the year 1995.

It is apparent that the Conceptual Framework for a FoF coalition team had to address these objectives from a perspective not used in more conventional ICAM projects. That perspective was from the aerospace enterprise (specifically the General Manager) point-of-view as opposed to the shop floor point-of-view. Our resultant system view, was therefore of a sophisiticated, complex social/technological system - the aerospace enterprise - a dynamic, self-regenerative entity that is constantly evolving and growing.

This redefined aerospace enterprise was the result of extensive research and industry review of the current conditions, needs and technologies involved in the manufacture of aero structures. Appendix A of this volume contains the results of a review of project results by a panel of noted manufacturing and computer authorities conducted in May of 1983. Members of this panel were:

- o Mr. Harvey Buffum (independent consultant)
- o Dr. Joseph Harrington, Jr. (Arthur D. Little)
- o Mr. James F. Lardner (VP Deere and Co.)
- o Professor Wickham Skinner (Harvard Business School)
- o Mr. Richard Spears (Boeing Computer Services Co.).

Based upon these research results a Conceptual Framework that effectively and efficiently integrates operations in the aerospace enterprise was established. This framework is based upon:

- o FoF Generic Functions
- o FoF Functional Framework
- o FoF Integration Concept
- o foF Conceptual Framework.

The FoF generic functions (figure 2-1) illustrated below in ICAM IDEF0 function model format are quite familiar. In fact, they are the same functional elements that an aerospace enterprise requires today. Our research results indicate that these generic functions will not differ significantly in 1995. However, our analysis did indicate that thie discrete mechanisms for performing these functions (e.g., Design Engineering, Manufacturing Engineering, QA/QC, etc.) dramatically change as new computer techniques and technologies are developed and implemented.

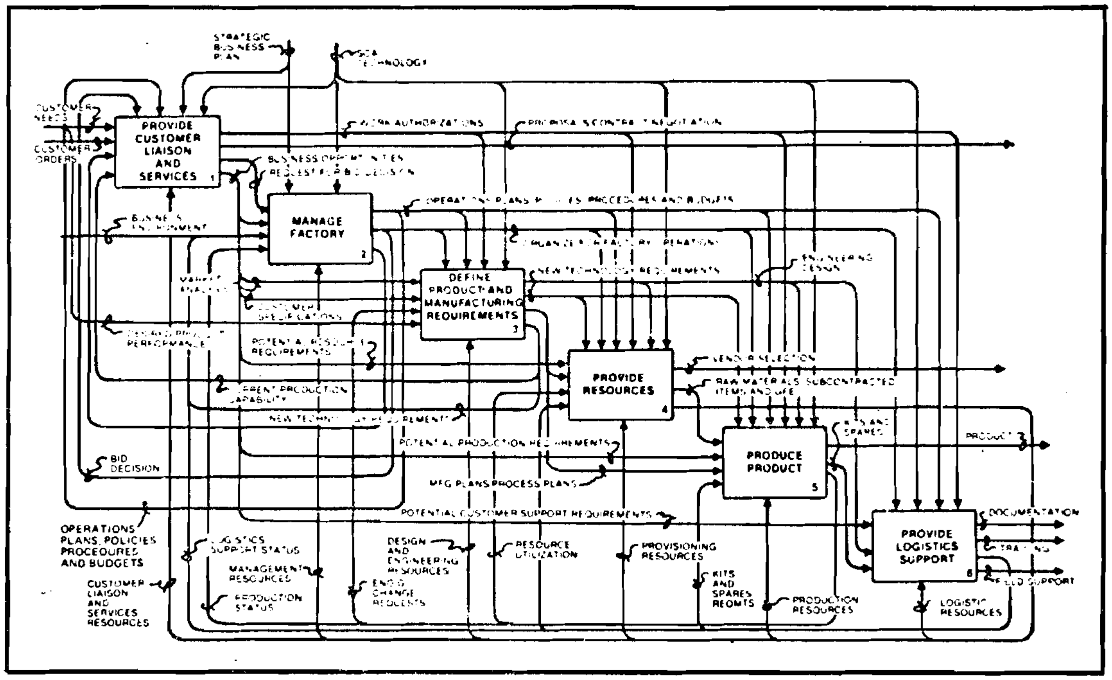


Figure 2-1 FoF Generic Functions

Once the generic functions were identified, a functional framework for the FoF environment was established (see figure 2-2). This resulting structuring of information and activity, as illustrated, reflects a realignment of the organizational structure within the enterprise based upon functional relationships. The superimposition of the information network and the factory management function upon the other functional elements emphasizes the idea that integrated management of the FoF requires an effective and comprehensive information transfer network.

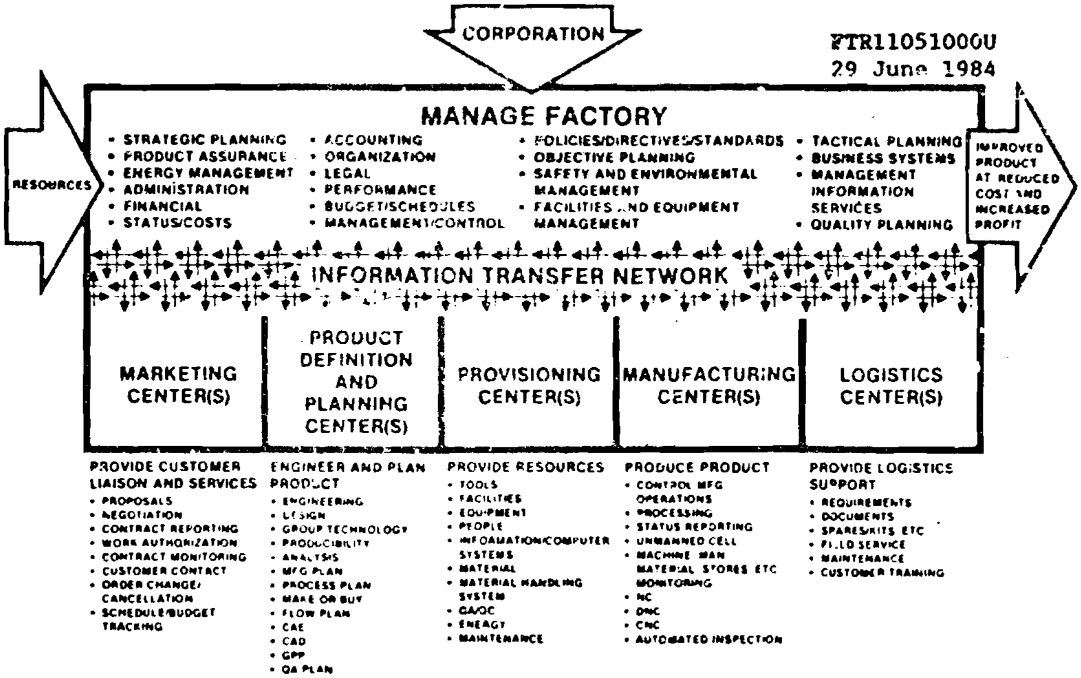


Figure 2-2 FoF Functional Framework

The FoF Integration concept evolved from the detailed analysis of needs for the 1995 aerospace enterprise. Over 400 distinct and separate needs were identified for the "TO-BE" aerospace enterprise. Once these needs were pinpointed, they were, in turn, categorized into primary functional needs corresponding with the FoF Functional Framework (See Figure 2-3).

FACTORY MANAGEMENT				
INTEGRATE FACTORY ACTIVITIES AND INFORMATION TO IMPROVE: • TRANSLATION OF STRATEGIC BUSINESS PLANS INTO TACTICAL AND OPERATIONAL PLANS • MANAGEMENT OF INFORMATION FINANCES AND RESOURCES • PRODUCT ASSURANCE • MANAGEMENT OF TECHNOLOGICAL CHANGES • DECISION SUPPORT				
MARKETING CENTER(S)	PRODUCT DEFINITION AND PLANNING CENTER(S)	PROVISIONING CENTER(S)	MANUFACTURING CENTER(S)	LOGISTICS CENTER(S)
PROVIDE CUSTOMER LIAISON AND SERVICES TO ACHIEVE	DEFINE PRODUCT AND PRODUCTION TECHNOLOGY REQUIREMENTS TO PROVIDE	SUPPLY RESOURCES THAT RESULT IN	PRODUCE THE END PRODUCT WITH	PROVIDE LOGISTICS SUPPORT THAT RESULTS IN
• REDUCED COST AND LEAD TIME FOR MARKETING ACTIVITIES • BETTER PROPOSALS • IMPROVEMENTS IN – INFORMATION MANAGEMENT AND COMMUNICATIONS BETWEEN MARKETING AND OTHER FACTORY FUNCTIONS – CONTROL OF MARKETING ACTIVITIES – MARKETING DECISIONS	• REDUCED ENGINEERING COSTS AND LEAD TIMES • BETTER PRODUCT DESIGNS • IMPROVEMENTS IN – MANUFACTURING PLANS – EQUIPMENT AND FACILITY DESIGNS – INFORMATION MANAGEMENT AND COMMUNICATION BETWEEN ENGINEERING AND OTHER FACTORY FUNCTIONS – CONTROL OF ENGINEERING ACTIVITIES	• REDUCED COST AND LEAD TIME • HIGHER QUALITY OF RAW MATERIALS AND PURCHASED COMPONENTS • IMPROVEMENTS IN – FACILITIES EQUIPMENT AND TOOLS FOR BOTH THE OFFICE AND THE FACTORY FLOOR – MANAGEMENT OF INFORMATION RESOURCES AND HUMAN RESOURCES – CONTROL OF PROVISIONING ACTIVITIES	• REDUCED MANUFACTURING COST AND LEAD TIME • HIGHER MORE CONSISTENT PRODUCT QUALITY • BETTER PRODUCTION SCHEDULE PERFORMANCE • IMPROVEMENTS IN – INFORMATION MANAGEMENT AND COMMUNICATIONS BETWEEN MANUFACTURING AND OTHER FACTORY FUNCTIONS – MANAGEMENT OF MANUFACTURING ACTIVITIES	• REDUCED LOGISTICS COST AND LEAD TIME • BETTER MANUALS TRAINING AND FIELD SERVICE • IMPROVEMENTS IN – PROVISIONING OF KITS AND SPARES – INFORMATION MANAGEMENT AND COMMUNICATIONS BETWEEN LOGISTICS AND OTHER FACTORY FUNCTIONS – CONTROL OF LOGISTICS ACTIVITIES

Figure 2-3 FoF Needs by Function

Further refinement led to the classification of the identified needs in seven major need categories. These categories are:

- o Information Resource Management (IRM)
- o Factory Management
- o Product Definition and Planning
- o Product Assurance
- o Human Resource Management (HRM)
- o Financial Management
- o Materials Management.

These categorized needs provide the basis for the functional integration of all projected FoF activities through the 1995 time frame. These need categories are guiding concepts for the integration of aerospace enterprise operations. As a result, they are specifically applicable to all FoF aerospace functions and cannot be isolated from those functions. Figure 2-4 illustrates (conceptually) this integration concept.

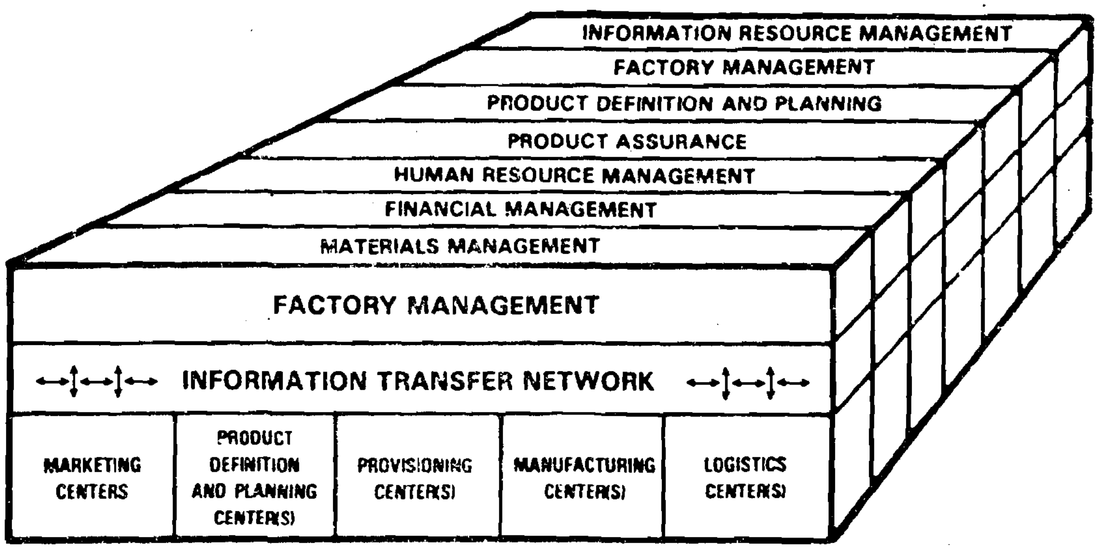


Figure 2-4 FoF Integration Concept

Combining the above concepts into a simplified Conceptual Framework for a FoF, results in the framework illustrated in Figure 2-5. Key points to stress are: 1) that six centers on this diagram directly relate to the six generic functions illustrated in figures 2-1 and 2-2; 2) the common information and logical processes are representative of all enterprise knowledge and procedures; and 3) the connecting lines represent the information transfer network which radiates from the information and procedures hub and provides the necessary routes for integration of the aerospace enterprise functional activities.

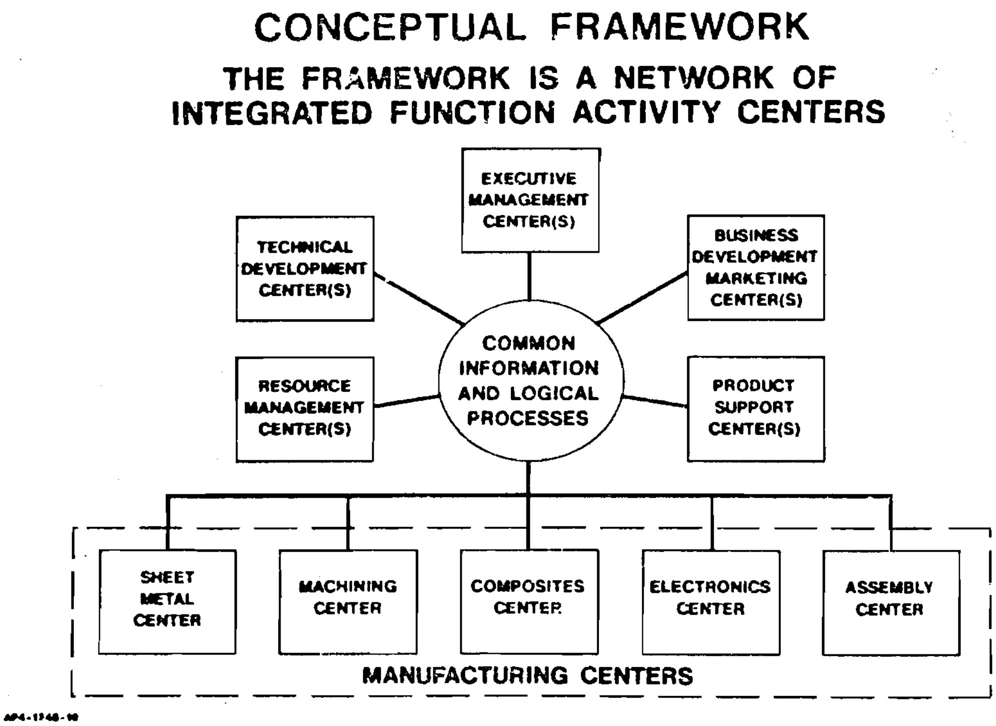


Figure 2-5 FoF Conceptual Framework

While the brief summary provides the essence of our FoF Conceptual Framework results, there are numerous and varied details which are vital to understanding this Conceptual Framework. There the reader is encouraged to read section 3.2 of this volume and Volume II, Part 6 of this Final Technical Report which describes the Conceptual Framework in detail.

2.3 Establish Integrated Composites Center Conceptual Design (Task C/E)

The use of non-metallic composite materials in the manufacture of aerospace structures has revolutionized production resource, information and operational requirements in the aerospace industry. Structures comprised primarily or entirely of composite materials are currently being produced by virtually every U.S. aerospace company for both military and commercial aircraft The structural enhancements of light weight, increased survivability and low visibility offered by the use of composites makes this the material choice for modifying existing aircraft as well as for next-generation aerostructures. In the future, composite materials will be used in primary aircraft structures (wings, fuselages, etc.) as well as their current use in secondary structures.

However, even though there is currently expanding use of composite materials by U.S. aerospace, present manufacturing methods are by and large very inefficient, labor intensive, and costly. The fabrication of composite strucutres in a non-automated manufacturing environment poses a number of serious issues relating to current production programs requiring composites. As the rate, complexity and size of composite structures increases with the design and manufacture of next generation aircraft, the current manual labor and suboptimal production techniques with their corresponding cost and quality considerations will become major stumbling blocks. To meet the demands of near-term and future composite aerostructure requirements, the development and implementation of computer and automated technology planning and production systems is essential.

In response to this critical need, the Integrated Composites Center task was included in ICAM Project 1105 with the following objective: "Establish preliminary designs and specifications for a computer-aided composites manufacturing center that integrates all activities required to produce composite components for small and large aircraft structures in an automated "paperless" factory.

Due to the clearly stated emphasis on industry-wide benefits from this Integrated Composites Center (ICC) effort, a coalition was formed to create the conceptual ICC design. This approach provided the best and most rapid means to disseminate ICC information to interested aerospace companies.

To enhance the validity and workability of project data, coalition team members completed individual site-specific preliminary designs within their aerospace manufacturing facilities. These individual efforts were then refined and melded into a collectively formulated generic preliminary ICC design. Further enhancements were made to this design, through the invaluable assistance and participation of a number of representative aerospace firms, technical experts and consultants.

As a result of these efforts, an ICC preliminary design was established with the following characteristics:

- o Conforms to an envisional 1990 manufacturing environment
- o Allows the production of a variety of composite aircraft structures to include:
  - Secondary structures, such as doors and panels
  - Primary strucutres, such as wings and fuselages
  - Specialized structures for fighter and transport aircraft
- o Facilitates fabrication to the subassembly level
- o Features material systems capable of handling:
  - Graphite/Epoxy
  - Kevlar
  - Feberglass
  - Thermoplastics
  - Graphite/Polymide
  - Graphite/Bismaleimide
- o Offers reuseable and disposable bagging
- o Provides a multitude of curing operations including:
  - Autoclave
  - Oven
  - Matched metal dies
  - Conventional temperature
- o Includes other essential composite manufacturing operations, such as:
  - Test and inspection
  - Trimming and drilling
  - Specialized material handling
  - Composite part rework
- o Moves forward in technology implementation and computer control with systems such as the Composites Management System
- o Emphasizes human factor considerations in special skills areas within the ICC
  - Composites Management System
  - Quality of Work Life

This brief summary provides an overview of the ICC effort. The reader interested in the detailed ICC preliminary design is referred to Volume III, Parts 1 through 10 of this final technical report.

2.4 Establish Quality Assurance/Quality Control Technical Requirements Tasks (Task D)

The U.S. aerospace industry has always set a very high priority on product quality, reliability, and maintainability. There are very few items produced by other businesses that equal the precision, endurance, and performance that are the hallmarks of aerospace products. Unfortunately, these self-imposed standards of product excellence have come to the industry at a high price.

In an effort to improve the industry's cost efficiency without jeopardizing its high quality standards, the USAF incorporated a quality assurance/quality control (QA/QC) task in ICAM Project Priority 1105 - "Conceptual Design for Computer Integrated Manufacturing." The QA/QC challenge was to identify computer-integrated technologies that would allow the aerospace industry to reduce product costs while maintaining traditionally high quality standards. To this end, key manufacturing areas that could contribute to product cost reductions through the implementation of computer technologies without adversely affecting QA/QC were identified.

The information developed in the QA/QC effort is applicable to a broad range of manufacturing scenarios. The project documentation (Volume IV, Parts 1 through 6 of this final technical report) provides guidelines for the use these USAF ICAM developed technologies in specific environments. Of prime importance, the data presented in the "Architecture for Product Assurance" (Volume IV, Part 5 of this technical report), offers a starting point to assess existing situations, to subsequently identify corrective steps, and to determine what levels of integration are needed to assure quality and productivity increases throughout the entire manufacturing cycle - from design and engineering to field use of the finished product.

Much of the application process outlined in the "Architecture for Product Assurance" has been undertaken, completed, and "road tested." The path to reducing costs and enhancing product quality through technology implementation begins with a series of critical questions. Answers to these questions within the context of a specific manufacturing scenario lead to the self-analysis necessary to begin technology implementation. Typical questions include:

- o Are quality requirements and activities considered only after the design is finalized?
- o Are there voids in the quality system that, once filled, would benefit customers as well as the company?
- o Are there any obsolete QA functions still being used?
- o Are there duplicated QA/QC functions anywhere within the manufacturing cycle?

- o Can the present quality system accommodate proposed changes such as:
  - Introduction of new products?
  - Addition of robotics to existing automation?
  - Adoption of inventory control measures for "just-in-time" material/part provisioning?
  - Introduction of CAD/CAM?
  - Transition from a centralized computer system to a distributive system?

If, within the context of a specific manufacturing scenario, the first four questions are answered "No," and the applicable sections of the fifth question are answered "Yes," the the firm is ready to answer the ultimate question related to this project task:

- o Is cost-effective QA/QC factored into the company's plans for automation technology application?

The answer to this query can ultimately be obtained through the use of the modeling and analysis tools developed as a result of this QA/QC task. These tools are presented in detail in Volume IV of this report.

Based upon reported applications and successful uses of this projects results, this project was recognized in 1984 as one of the past years "Top 10" examples of manufacturing technology successes by the Office of the Undersecretary of Defense for Research and Engineering.

2.5 Conclusion

The ultimate conclusion reached during this effort was that there are no pat answers or tailored-made guides that lead to instant solutions for current cost, productivity, and quality issues. Project 1105 tasks did identify systematic methods and tools for analyzing the manufacturing issues of today and, in so doing, provide a structure for developing alternative approaches that use computer driven technology to resolve these identified issues. These tools (which include the IDEF0 and IDEF1 modeling methodologies developed by ICAM) provide a logical process to structure current and future operations through the logical sequence of identified activities. The generic nature of these tools allows their use not only in the aerospace manufacturing arena, but universally in almost any manufacturing or service-oriented enterprise.

SECTION 3.0

PROJECT ACCOMPLISHMENTS BY WORK BREAKDOWN STRUCTURE (WBS)

SECTION 3

PROJECT ACCOMPLISHMENTS BY WORK BREAKDOWN STRUCTURE (WBS)

3.1 ESTABLISH MASTER PLAN AND SCHEDULE (TASK A)

The purpose of Task A was to develop a Project Master Plan and Schedule (PMP) for accomplishing the project objectives. Figure 3-1 is a simplified outline of this task. The PMP contained the strategy, approach, responsibility and description of deliverables associated with each contract requirement and was used as a monitoring and management mechanism thoughout the progress of this contract.

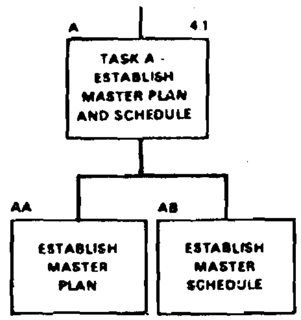


Figure 3-1. Task A Objectives by Work Breakdown Structure (WBS)

This task was completed and approved by the ICAM Program Management Office (PMO). The original PMP (PMP110510000) was published as part of ITR110510001U. One year after contract award, the document was updated to reflect changes. It was approved and released as PMP110510000A. This PMP was updated once more to reflect contract changes (PMP110510000B) in early 1983. These documents were used for managing and monitoring the activities of Project 1105.

3.2 FACTORY OF THE FUTURE CONCEPTUAL FRAMEWORK (TASK B)

The purpose of Task B was to Establish the Factory of the Future Conceptual Framework. An outline of the WBS items used to accomplish Task B is shown in Figure 3-2.

Specifically, the major objectives for Task B were:

- o To develop a strategy to achieve a computer-integrated framework concept that will integrate all major activities (e.g., Design, Finance, Marketing, QA/QC, Product Support and Manufacturing Planning)
- o To establish an overall Conceptual Framework that will describe these integrated activities
- o To create an aerospace enterprise framework structure that will serve as a baseline for computer-integrated manufacturing (CIM) initiatives through the year 1995.

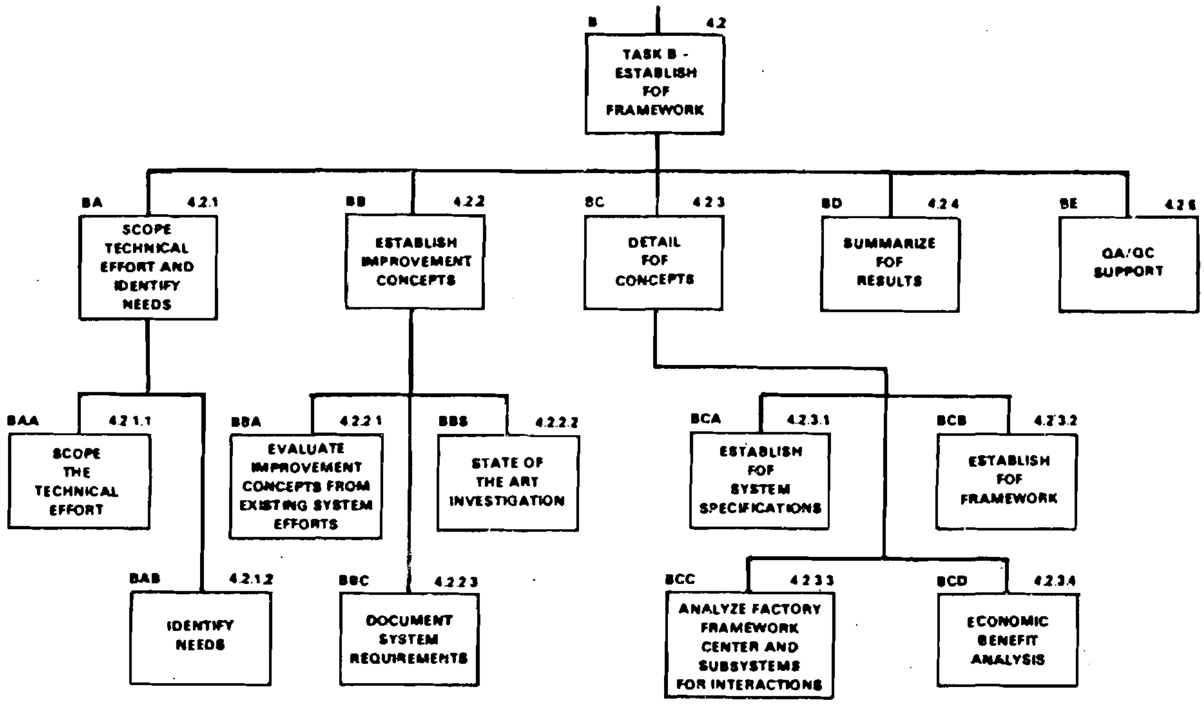


Figure 3-2. Factory of the Future Objectives by WBS

3.2.1 Scope The Technical Effort and Identify The Needs (WBS 4.2.1)

Under this task, statements of key needs were obtained from applicable ICAM, ManTech, Tech Mod and industry efforts. These needs were analyzed and addressed in two life cycle documents: the Scoping Document (SD) and the Needs Analysis Document (NAD).

In developing the Scoping Document (SD), SD 110512000 the coalition established two major goals.

- To develop a strategy to achieve a computer-integrated manufacturing (CIM) conceptual framework that integrates/interfaces/interacts with all major activities of the enterprise (e.g., design, finance, marketing, quality assurance/quality control, product support and configuration management) through the 1995 time-frame.

- To design an overall conceptual framework that includes multipurpose production centers (i.e., assembly, machining, electronics, composites and sheet metal).

Together with these goals, the team proceeded to identify needed enabling technology for implementing and managing CIM activities (i.e., areas requiring additional work). Applicable documents were identified and terms and abbreviations were defined.

The coalition team knew that to achieve the stated CIM objectives of the FOF framework all activities of the aerospace manufacturing company from marketing through product delivery and support must be systematically integrated to assure that computer driven application would result in optimal operations.

- Marketing of the product, submitting customer proposals and initiating contracts to provide products and services

- Engineering the products, manufacturing processes, tools, equipment, facilities and computer systems

- Acquiring, installing and managing resources

- Fabricating sheet metal, machined and composite parts and assembling the components into final products

- Planning, evaluating, testing, inspecting and controlling to assure product quality and performance

- Providing clear operation and maintenance instructions and field support to customers after product delivery.

The coalition realized that the Group Technology Concept suggested an ideal hierarchical control structure for total enterprise operations. This control structure would consist of a factory which managed one or more centers. Each center would manage one or more cells which, in turn, managed one or more stations. As a result, each station would perform one or more processes to accomplish the objectives of the organization.

Research showed that current programs were pursuing the design and demonstration of integrated centers for sheet metal, machining and composite fabrication as well as integrated centers for assembly and electronics. These centers would likewise be recognized as a part of the FOF framework.

The Task B coalition initially envisioned the functional structure of the FOF as depicted in Figure 3-3. Factory level management received policies and directives from corporate level management and were charged with conducting successful aerospace enterprise operations.

The Scoping Document identified five viable centers of functionally related activity within the control of factory level management.

(1) The Marketing Center which would provide customer liaison and services to initiate product development and production.

(2) The Product Definition and Planning Center which included the activities of design engineering and manufacturing planning in defining the product and production technology and quality requirements.

(3) The Provisioning Center which acquired all materials, tools, facilities, equipment and people required to accomplish the factory's function.

(4) The Manufacturing Center wherein the fabrication and assembly of the product occurred.

(5) The Logistics Center which included such items as product operating and maintenance documents, field service, field training detachments and the providing of spares and kits.

Out of these centers, all product requirements exist; such as design, material requirements, process planning, quality planning, tooling and facilities which are product/production-oriented. All the products and technology requirements were functionally related.

In developing the Scoping Document, several trends were immediately apparent to the coalition:

- Few activities performed actual physical production steps
- Several activities were involved in management decision-making
- Each activity had a parallel activity which was communication of information to other relevant activities
- Budgeting and cost-estimating were not adequately defined to determine their influence on the FOF
- Design should be viewed as a product itself to be scheduled, performed and evaluated.

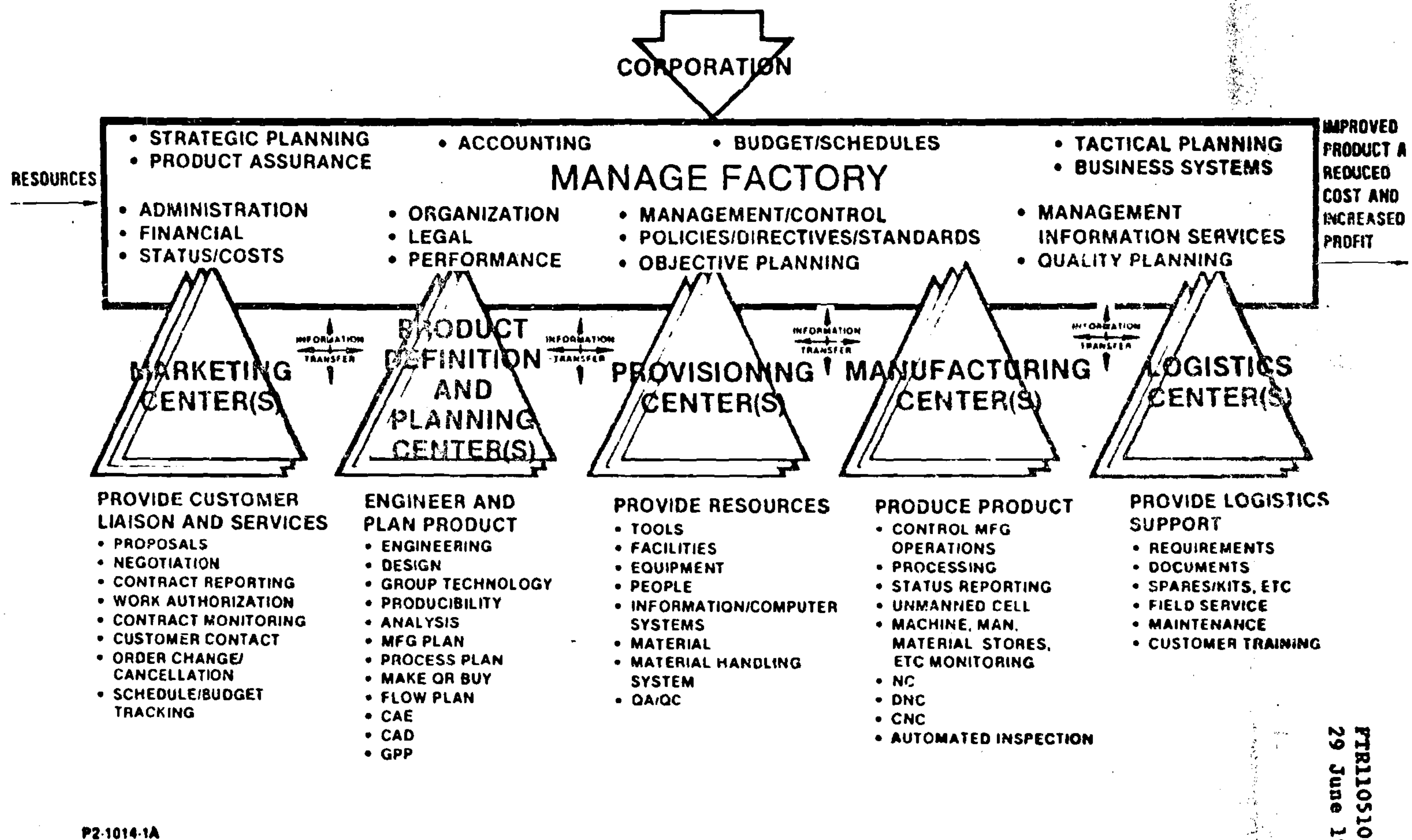


Figure 3-3. Factory of the Future Functional Framework Structure

From these trends, several conclusions were drawn:

- Production-oriented design must include process planning and quality planning
- Actual physical production steps are only a small part of the overall process of a manufacturing Enterprise
- Up-front planning is a key area
- Management decisions affect the ability to plan for and accomplish the activity
- The Factory of the Future must have a common information system whether it is a computer data base or a manual system.

The coalition submitted the results of this analysis in the FoF Scoping Document as Report Number SD 110512000 dated 25 March 1982. (Refer to Volume II, Part 1 of the Final Technical Report).

The Needs Analysis Document (NAD) NAD110512000, dated 10 May 1982 (refer to Volume II, Part 2 of the Final Technical Report), expanded the Factory of the Future environment in terms of concepts for cost drivers, human factors and other activities performed for the system identified as Task B, ICAM Project Priority 1105, Conceptual Design for Computer-Integrated Manufacturing.

The needs and voids in today's environment that had to be incorporated in the "To-Be World" through 1995 were identified by the coalition. From this study, some 400 needs were identified. These 400 needs were broken down into 36 categories and these broad 36 categories were simplified into 7 major categories as follows:

- Information Resource Management
- Management and Control
- Product Definition and Planning
- Product Assurance
- Human Resource Management
- Materials Management
- Financial Management

The results of the Needs Analysis document were used as the basis for developing the requirements for the FOF through the 1995 time frame. These requirements were detailed in the Systems Requirement Document (SRD), dated 3 March 1983. (Refer to Volume II, Part 4 of the Final Technical Report).

Five general goals were established by the coalition. These goals are common to any industry which desires to improve its competitive position and increase its productivity.

- o Reduce cost/price and increase profits
- o Improve quality
- o Improve Human Resource Management
- o Reduce time from customer order to product delivery
- o Improve manufacturing flexibility

As their approach to the Needs Analysis Document, the coalition conducted an extensive review of the literature then scheduled many meetings to discuss the technical aspects of the FOF conceptual framework. Figure 3-4 illustrates the revised FOF framework that evolved from these meetings and Figure 3-5 is the IDEFØ which supports the FoF framework illustration.

A detailed review of ICAM technical reports, ManTech reports, Tech Mod reports and general trade publications led to the development of the technological needs as shown in Figure 3-6. In this figure, the needs are described in abbreviated form as they pertain to each of the five centers that evolved under the manage factory concept. A more detailed description of these needs and activities can be found in the Needs Analysis Document which was submitted to the Air Force on 10 May 1982 as Document NAD110512000.

Once the goals, the technology, and the key needs were determined, the main question was, "How will these changes occur in the factory?" Only rarely will the opportunity exist in industry to build completely new factories. In most cases, the Factory of the Future must be introduced in an evolutionary manner. Seven areas of consideration were identified for this evolutionary, introduction of the FoF. The basic questions raised in each area were:

- o What functions/activities/concepts will be added, deleted or changed for the FOF? How should the old functions/concepts be phased out and the new ones phased in?
- o Under what situation should various available technologies be used? Is there a preferred sequence for implementation?
- o What limitations or opportunities exist for reorganizing factory resources?
- o How should the conceptual organizational structure be changed to accommodate the application of new technologies? How will these changes affect the human skills requirements?

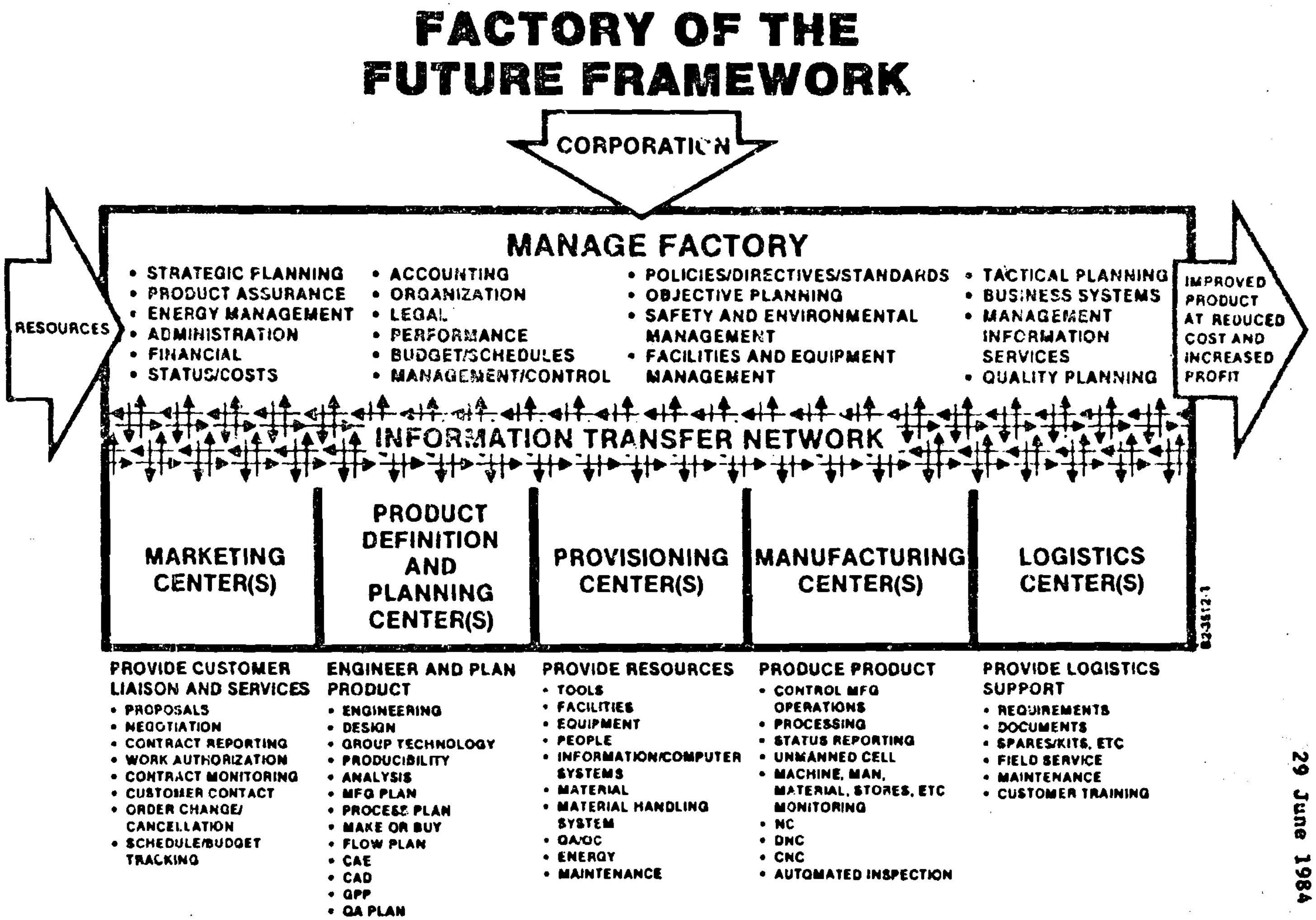


Figure 3-4. Factory of the Future Framework

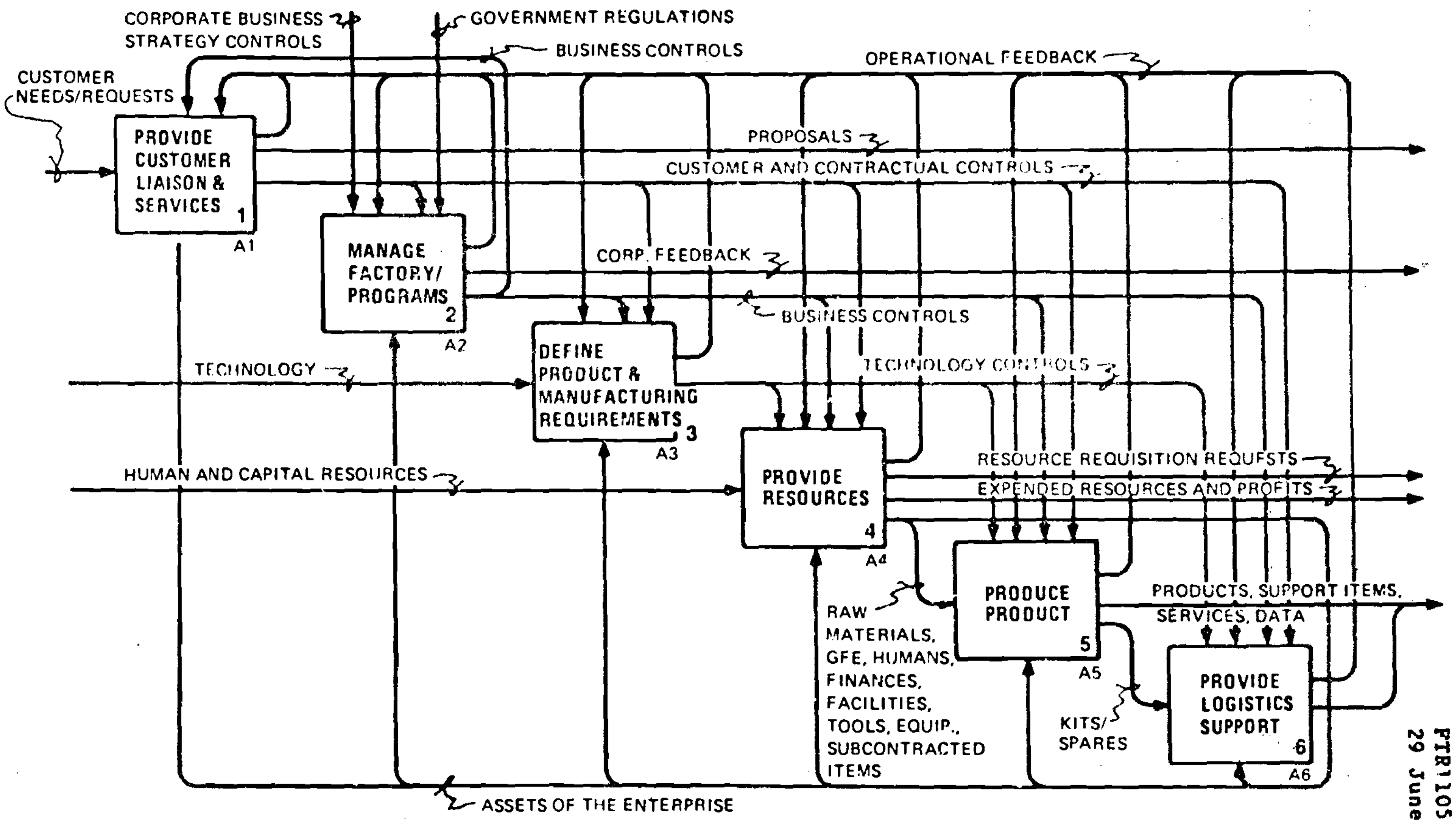


Figure 3-5. FoF/A0 Diagram

Task B Needs Analysis Document (NAD)

The analysis tool to determine system requirements

- Used by ICAM PMO and contractor as a record of system needs
- Identifies shortcomings in AS-IS environment
- Defines Factory of the Future goals
  - Reduce cost/price and increase profits
  - Improve quality
  - Improve human resource management
  - Reduce time from customer order to product delivery
  - Improve manufacturing flexibility
- Documents TO-BE system needs
  - More than 400 needs
  - Seven needs categories
- Conceptualizes systems for improvement
- Provides baseline to develop requirements for Factory of the Future in 1995
- Initiates concepts for cost and performance drivers in the Factory of the Future

Seven Categories of Needs Are Addressed by the Functional Areas in the Factory Framework

Identified Needs Categories	Functional Areas: Marketing	FOF Management	Product Definition and Planning	Provisioning	Manufacturing	Logistics
Information Resource Management	P	P	P	P	P	P
Management and Control	P	P	P	P	P	P
Product Definition and Planning	P	X	P	P	P	X
Product Assurance	X	P	P	X	P	P
Human Resource Management	X	P	X	P	X	X
Material Management	X	X	X	P	X	X
Financial Management	X	P	X	X	X	X

Legend: P = Primary Driver
X = Area of Need Consideration

Factory Management

Integrate Factory Activities and Information To Improve:

- Translation of Strategic Business Plans into Tactical and Operational Plans
- Management of Information, Finances and Resources
- Product Assurance
- Management of Technological Changes
- Decision Support

Marketing Center(s)

Provide Customer Liaison and Services to Achieve:

- Reduced Cost and Lead Time for Marketing Activities
- Better Proposals
- Improvements in
  - Information Management and Communications between Marketing and Other Factory Functions
  - Control of Marketing Activities
  - Marketing Decisions

Product Definition and Planning Center(s)

Define Product and Production Technology Requirements to Provide:

- Reduced Engineering Costs and Lead Times
- Better Product Designs
- Improvements in
  - Manufacturing Plans
  - Equipment and Facility Designs
  - Information Management and Communication between Engineering and Other Factory Functions
  - Control of Engineering Activities

Provisioning Center(s)

Supply Resources that Result in:

- Reduced Cost and Lead Time
- Higher Quality of Raw Materials and Purchased Components
- Improvements in
  - Facilities, Equipment and Tools for Both the Office and the Factory Floor
  - Management of Information Resources and Human Resources
  - Control of Provisioning Activities

Manufacturing Center(s)

Produce the End Product with:

- Reduced Manufacturing Cost and Lead Time
- Higher, More Consistent Product Quality
- Better Production Schedule Performance
- Improvements in
  - Information Management and Communications between Manufacturing and Other Factory Functions
  - Management of Manufacturing Activities

Logistics Center(s)

Provide Logistics Support that Results in:

- Reduced Logistics Cost and Lead Time
- Better Manuals, Training and Field Service
- Improvements in
  - Provisioning of Kits and Spares
  - Information Management and Communications between Logistics and Other Factory Functions
  - Control of Logistics Activities

Figure 3-6. Technological Needs

- o What management concepts, controls and objectives should be used to implement and operate the FCF?

- o How will the new communication and information management concepts be implemented? What will be their affect on the rest of the factory?

- o What new accounting and financial management methods will be required?

Feasible answers to these questions were discussed in detail in the Needs Analysis Document submitted to the Air Force on 10 May 1982.

Other needs, such as economic conditions in national and world economy, market conditions in the defense industry, management style and the introduction of new product technologies were not addressed as they were outside the scope of this document.

Pages 3-38 through 3-46 of the Needs Analysis Document (NAD110512000) contain a series of matrices developed by the coalition to simplify understanding and to emphasize needed future task efforts. These matrices relate the connection between the detail FOF functional needs and the seven generic needs categories established earlier in this discussion. Based upon the relationships shown in the matrices, the following conclusions were drawn:

- o Information Technology and Information Resource Management are essential building blocks for the FOF.

- o It is impossible to separate management of the factory from the requirement for Information Resource Management.

- o Combining engineering functions is essential in enhancing productivity.

- o Quality assurance improvements will increase productivity.

- o Resolution of personnel problems are as vital as resolution of problems relating to the selection and implementation of technology.

- o Strict materials management is having the right material, at the right place, on time and at reasonable cost is a vital concern of management.

- o As more functions are automated, the direct-to-indirect labor ratio will change drastically; consequently, new financial management procedures must be developed.

It was generally agreed by the coalition that the "glue" necessary to bind all the functions together would be the communication links between activities. Concepts had to be developed based on providing reliable communications between various activities. The Computer-Based Information Systems (CBIS) (ICAM Priority 3101) dealt with this in considerable detail. This CBIS structure provided the coalition with the basis to develop concepts for Information Resource Management.

One of the need categories, management and control was emphasized with control as a critical issue of management. It included such activities as the development and implementation of policy, establishing quality assurance directives, setting objectives and shaping employee relations.

Another primary need category identified by the coalition was Product Definition and Planning. Product Design is necessarily constrained by the functional requirements of the product and by the factory's manufacturing capabilities. Design must be evaluated in terms of manufacturing costs and time. Therefore, a method must be developed by which the designer can access current information on manufacturing capabilities and the costs of various alternatives. Product design, then, is translated into a product definition which can be separated into two distinct categories; geometric and non-geometric data.

All the other need categories (i.e., Product Assurance, Human Resource Management, Materials Management and Financial Management) are also vital to the conceptualization of the FOF. It is not valid to assume that these need categories are less important than the ones discussed above. All should be considered of equal status.

A complete discussion of all needs categories may be found in the Needs Analysis Document of 10 May 1982.

3.2.2 Establish Improvement Concepts (WBS 4.2.2)

The purpose of this task was to establish a set of improvement concepts based upon the need categories in the form of requirements that addressed the framework of the integrated Factory of the Future. The coalition investigated computerized information flow, strategic and tactical planning, management and decision support areas at all levels to accomplish this task. The accomplishment of this task was reported to the Air Force in State-of-the-Art Document SAD 110512000 dated 20 September 1982. (Refer to Volume II, Part 3 of the Final Technical Report).

This section of the Statement of Work tasked the Contractor to evaluate each system level improvement concept proposed or being pursued by industry, to evaluate the impact of each improvement and to show how many of the improvements, if implemented in the ICAM planning and control area, would benefit the various shop centers.

The coalition reviewed the state-of-the-art in commercially available technologies that could be used, but which were not being currently employed, plus needed technologies which would possibly satisfy the improvement concepts. A visual summation of this review is depicted in Figure 3-7.

Where appropriate, technology which was being developed but had not yet been proven cost effective was included in the document. The major emphasis was on commercially available technology which could possibly fulfill the needs identified in the Needs Analysis Document.

Task B State-of-the-Art Document (SAD)

An assessment of the most current technology to fill Factory of the Future needs

- Emphasizes commercially available technology
- Identifies technology voids in terms of the needs categories defined in the NAD
- Reviews selected Air Force priority projects
- Evaluates selected data base management systems and local area computer networks
- Analyzes an existing computer-integrated factory

"As the survey was completed...new advances were announced. In such a rapidly changing environment, the document provides a summary snapshot of what is available and an indication of what can be expected."
Task B State of the Art Document, page 1 8

Assessed Needs Categories To Identify Technology Voids

- INFORMATION RESOURCE MANAGEMENT
- FACTORY MANAGEMENT
- PRODUCT DEFINITION AND PLANNING
- PRODUCT ASSURANCE
- HUMAN RESOURCE MANAGEMENT
- MATERIAL MANAGEMENT
- FINANCIAL MANAGEMENT

Monitored ICAM, ManTech and Tech Mod Projects for State-of-the-Art Impact

ICAM PROJECT PRIORITIES

- 1104 MANUFACTURING ARCHITECTURE (SOFTECH)
- 2104 SHEET METAL FABRICATION SYSTEMS
- 2201 INTEGRATED SHEET METAL CENTER DESIGN
- 3101 COMPUTER BASED INFORMATION SYSTEMS (A D LITTLE)
- 4503 MANUFACTURING COST DESIGN GUIDE COMPUTERIZATION
- 5202 GROUP TECHNOLOGY CHARACTERIZATION CODE (VOUGHT)
- 5301 MATERIAL AND PROCESS MODELING (RTI)
- 5501 INTEGRATED PLANNING SYSTEM (GE)
- 6103 MCMM STATION AND CELL DEMONSTRATION (GE)
- 6201 MCMM CENTER DESIGN (GE)
- 7101 ASSEMBLY CENTER REQUIREMENTS (NORTHROP)
- 8205 ICAM DECISION SUPPORT SYSTEM
- 9301 MATERIAL FLOW CHARACTERISTICS

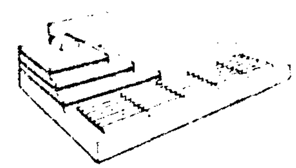
MANTECH PROGRAMS

- 01N471 - 1B034205 LARGE AIRCRAFT COMPOSITE STRUCTURES
- 18E572 - 1X086101 ELECTRONICS CAD/CAM
- 11M350 - 1A022003 ADVANCED MACHINING SUBSYSTEMS
- 11N432 - 1A032105 COMPOSITE ASSEMBLY PRODUCTION INTEGRATION
- 11M241 - 1A041202 ADVANCED SECOND LAYER NDE SYSTEM PRODUCIBILITY
- 11N409 - 1A034004 COMPLEX COMPOSITE FUSELAGE SHAPES

TECH MOD PROGRAMS

- 110001 - 1A120001 WESTINGHOUSE
- 110002 - 1A120002 GELAC/AVCO
- 110003 - 1A120003 BOEING MILITARY AIRCRAFT COMPANY
- 110004 - 1A120004 F 18 SUBCONTRACTORS

Analyzed Existing Factory of the Future Environment at Ingersoll Milling Machine Company*



* Received LEAD award from Computer and Automated Systems Association (CASA) for developing and implementing computer integrated manufacturing (CIM)

Assessed Local Area Computer Networks To Connect Separate Users

NAME	VENDOR/DEVELOPER	TOPOLOGY	ACCESS METHOD
CAMBRIDGE	CAMBRIDGE UNIVERSITY	RING	TDMA (TOKEN)
CLUSTERBUS	NESTAR SYSTEMS	BUS	TDMA (CSMA)
ETHERNET	XEROX CORP	BUS	TDMA (CSMA/CD)
FLASHNET	FORD AEROSPACE	RING	TDMA (TOKEN)
HYPERCHANNEL	NETWORK SYSTEM CORP	BUS	TDMA (CSMA/CD)
ILLINET	UNIVERSITY OF ILLINOIS	RING	TDMA (TOKEN)
LCS RING	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	RING	TDMA (TOKEN)
MITRENET	MITRE CORP.	BUS	FDM, TDMA (CSMA/CD)
MODWAY	GOULD MODICON	BUS	TDMA (TOKEN)
NET/ONE	UNGERMANN BASS, INC	BUS	TDMA (CSMA)
WANGNET	WANG LABORATORIES, INC	BUS	FDM, TDMA (POLLED)
Z NET	ZILOG CORP	BUS	TDMA (CSMA/CD)

Evaluated Selected Data Base Management Systems for Management of Information within the Factory

- ENCOMPASS
- ORACLE
- DATACOM/DB
- NOMAD 2
- SQL/DS
- INQUIRE AND IQ/NET
- PRIME DBMS
- DM-IV
- INGRES
- SEED
- TOTAL
- DBMS 10, DBMS-20
- IDMS

Figure 3-7. Task B State-of-the-Art Document (SAD)

FTR110510000U
29 June 1984

The goal of the State-of-the-Art Document was to investigate the information/communication technologies which were the key tools for integrating the FoF under the Manage Factory function. The primary focus was on the most current technology with a demonstrated potential for cost effectiveness. Many of these technologies are of the 1983 vintage. While these technologies will change rapidly, manufacturing's needs will change more slowly.

It was obvious that the primary concept which was needed to bind together the Factory of the Future activities was the communication links between the activities. The Computer-Based Information Systems Project (ICAM Priority 3101) dealt with this in considerable detail. By creating the concept of a "neutral data structure," the information common to multiple activities could be described. This neutral data structure could then be used as a framework for the common data base.

Appendix A of the State-of-the-Art Document contains a summary of data base management systems (DBMS) currently on the market. Not all available DBMS are included but only a representative group which describe a variety of features.

Various computer networks, hardware interface/terminals, human interaction with terminals, machine interaction and software interface are also described in detail in the State-of-the-Art Document.

As part of its task, the coalition investigated the development of the so-called "fifth-generation" computer. The concepts under scrutiny were:

- Intelligence interface to enable the input and output of information via speech, graphics, symbols and documents

- Knowledge-base management which will store relevant data bases so that an operator can retrieve information at any time

- Problem solving and inference which is the ability (in one form or another) to learn and make inferences from the knowledge stored in the data base.

Artificial intelligence (AI) uses a computer to mimic or supplement human intelligence in a decision-making context. It has two aspects: (1) a knowledge-base incorporating a set of information (or data) and its interrelationships, and (2) an inference procedure that "reasons" or selects the appropriate information for a particular situation.

Applications Technology - The 5th annual "Production Directory of Computers in Manufacturing" listed over 250 sources for manufacturing systems software. Commercially available technologies which are Information Resource Management oriented and addressed the other six needs categories were surveyed and evaluated at two levels. At the first level, the sources were state-of-the-art documents produced by ICAM projects. At the second level, the sources were promotional literature and directories on commercially available computer-integrated manufacturing (CIM) systems .

Because of the many mergers and acquisitions occurring in this market, it was impossible to ascertain which systems would be commercially available in the near future. However, it was not difficult to predict the characteristics of main systems. These are:

- o Increased accessibility and sharing of information
- o Improved flexibility and responsiveness
- o Improved integrity and timeliness

The manner in which these systems address other primary drivers of generic needs are shown in Figure 3-8.

Technology Voids - Technology areas which are not available to support subsystem requirements were identified in terms of the need categories. Due to the interactions between these need categories and their often long range implications, it was not possible to measure the impact of fulfilling the individual needs. The basic needs and their corresponding technological voids are summarized in Figure 3-9. A full discussion of these voids may be found in Section 3.0 of the State-of-the-Art Document which is Volume II, Part 3 (SAD110512000) of this Final Technical Report.

Key Concepts in Computer-Integrated Manufacturing - For its leading role in developing Computer-Integrated Manufacturing (CIM) the Ingersoll Milling Machine Company, received the 1982 LEAD Award from the Computer and Automated Systems Association of the Society of Manufacturing Engineers.

Out of their original research, Ingersoll adapted three pivotal strategies that bear importantly on the use of the computer in engineering and manufacturing.

- o First was the decision to use numerically controlled machines from the moment they were practically available
- o Second was the decision to employ computer-aided design (CAD)
- o Third was the decision (taken within the last three years) to rewrite all its information software programs to make it possible for the company-wide software system to organize and integrate all the data from all its programs (i.e., the start of the logical common data base of the FoF). This was the start of their management and business information system.

FUNCTIONAL AREA (NODE NO.)	THE PRIMARY DRIVERS OF GENERIC NEEDS		THE STATE OF INTEGRATED SYSTEMS	
PROVIDE CUSTOMER LIAISON AND SERVICES (A1)	• MANAGEMENT AND CONTROL - IMPROVED PROPOSALS - IMPROVED CONTROL OF MARKETING ACTIVITIES - IMPROVED MARKETING SERVICES • PRODUCT DEFINITION AND PLANNING - REDUCE COST AND LEAD TIME FOR MARKETING ACTIVITIES		• MARKETING MODULES ARE DIRECTED TO HIGH VOLUME COMMERCIAL AND CONSUMER PRODUCT INDUSTRIES - RESULT FEATURES RELATING TO CONTRACT OPERATIONS ARE ABSENT	• MARKETING MODULES HAVE - ORDER TRACKING CAPABILITIES - SCHEDULE IMPACT EVALUATION - COST AND BILLING FEATURES • NONE OF THE MARKETING MODULES HAVE - PRODUCT DEFINITION AND PLANNING
MANAGE FACTORY OF THE FUTURE (A2)	• MANAGEMENT AND CONTROL - IMPROVED TRANSLATION OF STRATEGIC PLANS - IMPROVED MANAGEMENT OF RESOURCES AND TIME - IMPROVED MANAGEMENT OF TECHNOLOGICAL CHANGE - IMPROVED DECISION SUPPORT • PRODUCT ASSURANCE • HUMAN RESOURCE MANAGEMENT • FINANCIAL MANAGEMENT	CORRESPONDING MODULES ARE • MASTER SCHEDULING • CAPACITY PLANNING • MATERIAL REQUIREMENTS PLANNING • PRODUCTION CONTROL - WORK ORDER SCHEDULING - SHOP FLOOR DISPATCHING - WORK ORDER TRACKING	• PRIMARY OBJECTIVE IS TO PROVIDE MANAGEMENT AND CONTROL - FEEDBACK CONTROL FUNCTIONS ARE WEAK, BUT PROVISIONS TO GROW - NEEDS IN THIS CATEGORY SATISFIED EXCEPT IMPROVED MANAGEMENT OF TECHNOLOGICAL CHANGE • ONLY ONE SYSTEM ADDRESS PRODUCT ASSURANCE - ENGINEERING ANALYSIS AND ENGINEERING DATA COLLECTION SYSTEM - ABILITY TO SELECT, CORRELATE AND REPORT RESULTS ON ACTUAL PROCESS PARAMETERS - TRACEABILITY CAN BE MAINTAINED • HUMAN RESOURCES MANAGEMENT ALL SYSTEMS TO A REASONABLE DEGREE - REDUCE THE NUMBER OF MUNDANE JOBS - ENHANCE THE DECISION SKILLS OF PERSONNEL - IMPROVE COMMUNICATION	• NO MODULES RELATE TO ORGANIZATION STRUCTURE, MOTIVATION AND SKILL • ALL SYSTEM ADDRESS FINANCIAL MANAGEMENT - APPROACHES VARY SIGNIFICANTLY
DEFINE PRODUCT AND PRODUCTION TECH RQMTS (A3)	• MANAGEMENT AND CONTROL - IMPROVED CONTROL OF ENGINEERING ACTIVITIES • PRODUCT DEFINITION AND PLANNING - REDUCED COST AND LEAD TIME FOR ENGINEERING - IMPROVED PRODUCT DESIGNS - IMPROVED MANUFACTURING PLANS - IMPROVED EQUIPMENT AND FACILITIES DESIGN		• ALL SYSTEMS HAVE CAD AND CAE MODULES - NO SYSTEM CAN BE USED FOR ALL TYPES OF PRODUCTS - LINKS FROM INTEGRATED ENGINEERING TO OPERATIONAL PLANNING AND CONTROL ARE NOT COMPLETE, BUT SOME ARE MOVING IN THAT DIRECTION • THE SYSTEMS DO PROVIDE IMPROVED CONTROL OF ENGINEERING ACTIVITIES - BETTER USE OF PERSONNEL SKILLS - MORE EFFICIENT USE OF RESOURCES - CLOSER COORDINATION OF ENGINEERING PRIORITIES AND SCHEDULES	• NOT CLEAR THAT THEY PROVIDE MORE CONSISTENCY WITH BUSINESS OBJECTIVES • THE OBJECTIVE OF THESE MODULES IS TO - REDUCE COST AND LEAD TIME FOR ENGINEERING - IMPROVE PRODUCT DESIGN - IMPROVE MANUFACTURING PLANS • EQUIPMENT AND FACILITIES DESIGN IS AN AREA OF WEAKNESS - ONLY ONE SYSTEM EVEN ADDRESSES THIS AREA
PROVIDE RESOURCES (A4)	• MANAGEMENT AND CONTROL - IMPROVED CONTROL OF PROVISIONING ACTIVITIES • PRODUCT DEFINITION AND PLANNING - IMPROVED FACILITIES, EQUIPMENT AND TOOLS • HUMAN RESOURCE MANAGEMENT • MATERIALS MANAGEMENT - REDUCE COST AND LEAD TIME FOR PROVISIONING RESOURCES - IMPROVE RAW MATERIAL AND PURCHASED COMPONENTS	THE CORRESPONDING MODULES ARE • INVENTORY MANAGEMENT • MATERIAL ISSUES AND RECEIPTS • PURCHASE ORDER TRACKING	• THE MODULES ARE DESIGNED TO IMPROVE CONTROL OF PROVISIONING ACTIVITIES • THE MODULES DO NOT ADDRESS - THE QUESTION OF IMPROVED FACILITIES, EQUIPMENT AND TOOLS - HUMAN RESOURCE MANAGEMENT IN TERMS OF BETTER RECRUITING OF KEY PERSONNEL BETTER ORIENTATION AND INHOUSE TRAINING BETTER INCENTIVES AND EMPLOYEE MOTIVATION • IMPROVED UTILIZATION OF EMPLOYEE SKILLS AND CAREER DEVELOPMENT • A MAJOR OBJECTIVE OF THE MODULES IS TO REDUCE COST AND LEAD TIME - THE APPROACHES TO IMPROVING RAW MATERIAL AND PURCHASED COMPONENTS VARIES CONSIDERABLY - SOME HAVE EXTENSIVE VENDOR RATING SYSTEMS	
PRODUCE PRODUCT (A5)	• MANAGEMENT AND CONTROL - REDUCE COST AND LEAD TIME OF MANUFACTURING ACTIVITIES - IMPROVE RESULTS OF MANUFACTURING - IMPROVE MANAGEMENT OF MANUFACTURING ACTIVITIES • PRODUCT DEFINITION AND PLANNING		• OPERATION PLANNING AND CONTROL MODULES - THE MORE ADVANCED ARE GEARED FOR FACTORY AND PLANT AUTOMATION • THE MODULES ARE DESIGNED TO REDUCE COST AND LEAD TIME THROUGH - BETTER LOADING - BETTER SCHEDULING - MONITORING PERFORMANCE	• ONE SYSTEM CAN ANALYZE ENGINEERING AND PRODUCTION DATA - SHOULD LEAD TO HIGH QUALITY
PROVIDE LOGISTICS SUPPORT (A6)	• MANAGEMENT AND CONTROL - REDUCE COST AND LEAD TIME - IMPROVE CONTROL • PRODUCT ASSURANCE - IMPROVED FIELD SUPPORT		• CONSIDERED A MARKETING FUNCTION FOR CONSUMER AND COMMERCIAL PRODUCTS • EXISTING MODULES CAN - BE D TO PREPARE PRODUCT MANUALS - FORECAST REPLACEMENT PARTS - IMPROVE PRODUCT DESIGN	

Figure 3-8. Applications Technology Matrix

GENERIC NEED CATEGORY	BASIC NEEDS	THE VOIDS
INFORMATION	• A MECHANISM FOR INTEGRATION • PROVISIONS FOR DISTRIBUTED DATABASES (ON DISTRIBUTED MACHINES) • FLEXIBILITY TO THE END USERS • REDUCTION OF THE NEED FOR SOFTWARE • IMPLEMENTATION PLAN WHICH WILL: - MINIMIZE INITIAL IMPACT - BE ABLE TO EVOLVE	• PROCEDURE FOR CONVERTING A PROLIFERATION OF INDEPENDENT DATABASES INTO AN INTEGRAL SYSTEM • HARDWARE AND SOFTWARE PROTOCOL STANDARDS (SEMI) • COMPATIBLE HARDWARE • CUSTOMIZABLE SYSTEMS • COMMERCIALLY AVAILABLE TECHNOLOGY FOR IMPLEMENTATION
MANAGEMENT AND CONTROL	• TRUELY CLOSED-LOOP SYSTEMS • TIMELY-ACCURATELY-READILY AVAILABLE CONTROL INFORMATION FOR DECISION SUPPORT • IMPROVED LEVEL OF CONTROL SYSTEM RESPONSE TO CHANGE • IMPROVED TOOLS FOR DECISION SUPPORT	• COMPATIBLE MECHANISMS FOR DATA COLLECTION • REAL TIME DATA COLLECTION • HARDWARE AND SOFTWARE SUPPORT FOR DATA COLLECTION
PRODUCT DEFINITION AND PLANNING	• PRODUCT DEFINITION AND PLANNING INVOLVES SEVERAL DISCIPLINES (E.G., INTERACTIVE GRAPHICS, FINITE ELEMENT MODELING, SIMULATION) • A NEED FOR ALL DISCIPLINES TO BE NETWORKED ON A COMMON OPERATING SYSTEM • ADVANCES IN OTHER INDUSTRIES MAY OR MAY NOT APPLY TO A MODERN, HIGHLY COMPLEX AEROSPACE PROGRAM WITH THE VAST AMOUNT OF DETAIL AND CHANGE ACTIVITY • THE GREATEST BARRIER TO IMPLEMENTATION IS THE ORGANIZATIONAL IMPACT	- SAME AS NEEDS -
PRODUCT ASSURANCE	• IMPROVED ORGANIZATION INTERFACE DURING NEW PRODUCT INTRODUCTION • IMPROVED QUALITY INFORMATION SYSTEM • EFFECTIVE QA/QC FIELD INFORMATION, ACQUISITION AND UTILIZATION • NEW WAYS OF TEST AND INSPECTION • SOFTWARE QUALITY ASSURANCE	• EFFECTIVE MECHANISM OR NETWORK BY WHICH INFORMATION CAN BE COLLECTED AND COMMUNICATED • EFFECTIVE HISTORICAL DATABASE • "IN-LINE" QA/QC FUNCTIONS • SOFTWARE QUALITY ASSURANCE METHODS

83-2601-2(A)

Figure 3-9. Technology Voids Matrix

GENERIC NEED CATEGORY	BASIC NEEDS	THE VOIDS
HUMAN RESOURCE MANAGEMENT	• SKILL REQUIREMENTS • INFORMATION NEEDS • PRODUCT VS. PROCESS "FOCUS" • INVOLVEMENT • ORGANIZATION STRUCTURE • MOTIVATION • BETTER AND LONGER-TERM PLANNING • ORGANIZATIONAL DEVELOPMENT	SAME AS NEEDS EXCEPT FOR MODULES SUPPORTING: • REDUCTION OF MUNDANE JOBS • ENHANCING DECISION SKILLS • IMPROVED COMMUNICATION
MATERIAL MANAGEMENT	• IMPROVE COMMUNICATION WITH SUBCONTRACTORS • REDUCTION IN MATERIAL COSTS • IMPROVED WORK-IN-PROGRESS MANAGEMENT • MORE EFFECTIVE FACILITIES AND EQUIPMENT MANAGEMENT	• NOT IN THE TECHNOLOGY BUT IN THE APPLICATION OF WHAT IS AVAILABLE • THE INCENTIVE TO IMPROVE THIS AREA
FINANCIAL MANAGEMENT	• A NEW METHOD OF ACCOUNTING • A CONSOLIDATION AND STANDARDIZATION OF FINANCIAL DATA BASES • AUTOMATIC PART AND RESOURCE COST COLLECTION • IMPROVED MEASURES OF PERFORMANCE/PRODUCTIVITY • REDUCED INVENTORY COSTS • IMPROVED METHODS OF PRODUCING AND PRESENTING FINANCIAL INFORMATION • TOOLS FOR MORE ACCURATE BUDGETING • IMPROVED SYSTEMS FOR GENERATING ACCURATE MANUFACTURING COSTS FOR PARTS AND WHOLE SYSTEMS (AND LINK TO ENGINEERING TRADE-OFF STUDIES) • FORECASTING MODEL(S) • IMPROVED TOOLS FOR EVALUATING ROI/ROA • FINANCIAL SYSTEMS INTEGRATION WITH PRODUCTION CONTROL SYSTEMS	- SAME AS NEEDS -

83 7601-2(8)

Figure 3-9. Technology Voids Matrix (Concluded)

The main modules in the computer-integrated manufacturing system at Ingersoll are:

- o Master schedule
- o Engineering design
- o Inventory control
- o Purchase and accounts payable
- o Parts manufacturing and cost
- o Assembly

The whole structure is supported by the data base management system and accessed from 121 on-line computer terminals. This system is run in real-time with over one-half of their indirect labor force having their own personal computer access code. A breakdown of the Ingersoll system is presented in Section 4.0 of the September 1982 State-of-the-Art Document. (Refer to Volume II, part 3 of the Final Technical Report).

Appendix A of that Document furnishes a review of selected data base systems; Appendix B supplies a review of selected, previous ICAM state-of-the-art reviews.

Systems Requirements Task

The System Requirements Task identified the improvements needed to establish the conceptual framework of the Integrated Factory of the Future . The economic benefits and analysis was not accomplished at this time, since the concepts for aerospace factory improvements were not yet gelled into a total cohesive factory "system."

The System Requirements Document was the first functional document for the "TO BE" conceptual framework of the Factory of the Future. It detailed the seven generic needs categories identified in the FoF Needs Analysis Document as to their requirements. These needs categories established the basis upon which to establish the System Specification and the FoF conceptual framework.

The System Requirements Document expanded the seven needs categories by identifying specific requirements for each need:

- o Information resource management
- o Management of the factory
- o Product definition and planning
- o Product assurance
- o Human resource management
- o Materials management
- o Financial management.

Section 3.0 of the System Requirements Document identified and described functions that are projected to occur in the Factory of the Future as they related to the needs categories. This Document, as developed, examined the transition from the "AS IS" aerospace factory of today to the conceptual "TO BE" factory of 1995. Current "AS IS" deficiencies defined in the Needs Analysis Document were expanded into "TO BE" conceptual requirements which were used to further develop the FoF conceptual framework.

Appendices A through G of the System Requirements Document of 3 March 1983 contain a wealth of supporting data to substantiate and "flesh out" the identified factory-level system requirements. These appendices are vital to the understanding of the philosophy and the reasons "how" and "why" the coalition developed this particular FoF conceptual framework.

Information Resource Management - Manufacturing, in the ultimate analysis, is a series of information processing steps. As industry moves toward flexible manufacturing capabilities in the FoF, more and more information will be computerized. Such physical objects as templates and master models will be replaced with electronically stored data. This computerized information will begin to be viewed as a company resource. As a result, information will be the common company resource that affects every function within the Enterprise. It is apparent, then, that the efficient management of information is essential to the effective functioning of the FoF. The specific requirements are:

- o Information resource control
- o Information manipulation
- o Information application.

The coalition established certain criteria for these requirements to fulfill their functions. For example, the information control requirements had to provide a fully automated, intelligent data dictionary that would support the formal definition of the total factory information structure. This requirement also had to provide automated tools and techniques for the dynamic structuring of information to support application views of the factory and to provide information resource management standards and procedures with supporting computerized tools for programs which share common information.

Information manipulation requirements were classified into four categories:

- o To provide for the consistent, timely and accurate transmittal of information to all users
- o To provide information processing tools to support both automated and human controlled decision-making (e.g., artificial intelligence)
- o To make common information readily available to users through a friendly, interactive, natural command language

- To be able to store information in an efficient and flexible manner.

Information application requirements were defined as being able to provide mechanisms and techniques to capture, store, process and communicate information which reflected marketing and sales, business management, product definition and planning, procurement and material management, manufacturing and product support knowledge.

Management of the Factory - In analyzing the managerial operations within today's factory, it soon became evident that efforts to improve productivity and quality have yielded less than desirable results. The primary causes for this have been:

- Inadequate integration of corporate business objectives into factory operations
- Permitting suboptimization of one functional area's activities which, in turn, impacted other areas
- Inability to implement alternate plans and options
- Poor determination of resource requirements
- Poor allocation of existing resources
- Management's inattention to the impact of technological changes on current operations.

In examining these causes of management inadequacy, the coalition determined that to correct the problem it would be necessary (1) to provide management tools and procedures that generated realistic schedules for all factory activities; (2) to provide management tools and procedures to resource requirements and allocate those resources in an optimal manner, and (3) to provide management tools and procedures that support the identification, assessment, selection and implementation of vital new technologies.

Product Definition and Planning - This area encompassed two key elements:

- The Design Function - the requirement to define a more satisfactory product for the customer
- The Manufacturing Planning Function - the requirement to combine detail design, manufacturing technology and customer requirements into a plan to produce the more satisfactory product in an improved manner.

The following requirements are vital to the successful implementation of these key elements:

- o Interactive computer graphics
- o Group Technology
- o Automated process planning
- o Product definition and planning data base
- o Change handling flexibility.

These requirements are discussed in detail in the System Requirements Document.

Product Assurance - In the realm of product assurance, two vital areas were designated for examination:

- o Requirements specifically related to Quality Assurance/Quality Control
- o Requirements specifically related to Configuration Management.

The coalition determined that many new provisions had to be made in order to upgrade Quality Assurance and Quality Control procedures. These were:

- o To provide analysis tools and procedures for implementing quality during the design phase
- o To provide procedures and mechanisms to improve the inspection process
- o To provide a more efficient means for documenting nonconforming parts and materials
- o To provide an improved interface with manufacturing control
- o To provide procedures and mechanisms to integrate the flow of all QA information through the Enterprise.

In the field of Configuration Management, it was determined that improvements could be achieved by:

- o Providing tools and procedures to improve the identification, controlling and tracking of configuration items
- o Providing improved storage and maintenance of Configuration Management information
- o Providing procedures and mechanisms to integrate Configuration Management activities and information with other activities.

Human Resource Management - During the development and implementation of the FoF it will be essential to address the human side of automation and technological innovation. This is valid regardless of the innovation, be it a change in procedure or the design and construction of a new factory. Failure to consider the human side of the technological equation leads to results that do not equal expectations.

Factors contributing to this sensitive area are:

- o Employee's fear of losing their jobs
- o Managers fear of losing their power base
- o Organizational disruption
- o Inadequate training in the use and application of new systems, techniques and machines.

After gathering and analyzing an abundance of data, the coalition recommended five distinct requirements to reduce the negative factors listed above. These five requirements were identified and discussed under:

- o Human Resource Planning
- o System Development and Human Resource Integration
- o Training
- o Staffing
- o Employee Relations.

Each of these five areas were broken down further into coalition recommendations for overcoming resistance to implementing the FoF. Their recommendations are part of Section 3.0 and Appendix E of the System Requirements Document.

<u>Materials Management</u> - The importance of Materials Management was based upon two factors:

- o Control and distribution of the resources used in the production and product support activities

- o Material costs which represent a substantial portion of the investment in the finished product.

To be fully responsive to the FoF needs, Materials Management must provide the right facilities, materials or components in the desired quantity and quality, in the right amount, at the right time, in the right place and at reasonable cost. The coalition established two requirements for successful Materials Management; (1) the acquisition of resources, and (2) the planning and control of those resources.

Successful resource acquisition requirements demand establishing procedures for the effective selection of vendors, suppliers and subcontractors through:

- o Establishing a system for coding materials
- o Establishing an automated historical data base for vendors, suppliers and subcontractors

- o Establishing an automated purchase order and requisition system
- o Developing a mechanism with a common data exchange format to provide direct communication with vendors, suppliers and subcontractors
- o Establishing procedures that provide versatile production facilities with flexible equipment.

The Planning and Control of resources will mean providing tools and procedures to improve the development of Material Management plans that permit in real-time:

- o Determination of total material requirements
- o Determination of material availability and cost
- o Determination of subcontracted item availability
- o Consideration of "what if" factors
- o Establishment of procedures for more efficient use of resources by developing:
  - Improved scheduling techniques
  - More effective means of controlling inventory
  - Procedures and mechanisms to support integrated Material Management between various factory functions.

Financial Management - Financial Management consists of activities which involve: money or assets, means of evaluating alternatives, and comparing performance to improve the profitability of the Enterprise. Although a key goal of the FoF is to reduce costs/prices and increase profits, this is simply one aspect of the business operational cycle. The other goals deal with remaining in and acquiring new business.

Unfortunately, in the Factory of Today, the main financial emphasis has been focused on short-term profitability rather than on long-term profitability. Additionally, our current financial structure is predicated on a style which matches a theoretical framework rather than the actual operations and processes needed to produce the product. As a result, our current financial models neither reflect accurately on conditions, nor do they support long range planning for corporate development.

The coalition outlined five requirements which should be the goals of Financial Management in the FoF.

- o The accurate and timely collection, storage and manipulation of financial data

- o Tools and techniques for accurately forecasting and estimating financial trends

- o Tools and techniques for expanding financial analysis

- o Tools and techniques for more accurate, timely and efficient general accounting procedures

- o Tools and techniques for efficient management of cash and all other resources.

In addition to these five goals, a reorientation will be required to place financial information in its proper perspective as an important, but not all controlling, input for Enterprise decisions.

3.2.3 Detail Factory of the Future Concepts (WBS 4.2.3)

Under this task, the prioritized performance requirements for the "TO BE" Conceptual FoF Framework were established. Additionally, the performance requirements associated with the seven generic needs categories were summarized. The Conceptual Framework Document and IDEF0 models of the FoF were also developed under this task.

Framework System Specification

The System Specification Document (SS), SS 110512000, dated 14 October 1983 (refer to Volume II, Part 5 of the Final Technical Report) was developed under this task. An in-depth summary of specific performance requirements deemed essential for integrated aerospace factory operations through the year 1995 is presented. This was accomplished by expanding the conceptual requirements identified in the System Requirements Document (SRD) with the additional descriptions of the concepts as they relate to:

- o Functions that are to be performed or supported by the concept;
- o Performance characteristics dealing with speed, accuracy, and efficiency needed to satisfy the concept;
- o Physical characteristics identifying the hardware, facilities, tools, equipment, and materials needed to support the concept;
- o Operational characteristics dealing with methods, procedures, and policies needed to support the concept;
- o Information characteristics that identified the type of information required to satisfy specific concepts;
- o Interface characteristics that describe who (the user) or what (e.g., an application system) will be affected by the implementation of a specific concept;
- o Technology voids that could delay the implementation of a concept;
- o The impact on personnel at all levels when a particular concept is implemented.

Continuing with the procedure begun in the NAD these needed performance requirements and their associated characteristics were described and organized by Need Category.

3.2.3.1 Establish Factory of the Future System Specification (WBS 4.2.3.1)

Information Resource Management - Since, in the final analysis, manufacturing (computer aided or manual) is a series of information processing steps the coalition determined that the practice and application of Information Resource Management concepts is essential to the FoF. Even today, the trend towards replacing physical objects (e.g., templates, master models) with computer (digitized) models to convey manufacturing information is firmly established. As a result, the management and control of information as a company resource vis-a-vis individual or departmental resource is essential. To support this critical requirement for the 1995 aerospace enterprise, specific conepts (listed below) and discussed in detail in the SS document were presented:

- o Data definition
- o Data structuring
- o Application development
- o Communications
- o Decision support
- o Information processing
- o Information storage
- o Information application.

Management of the Factory - At the factory level, management issues are centered around planning and directing company resources, i.e., capital, humans, information and time. In establishing our seven major need categories, management of information, capital and humans are discussed separately. This need category focuses on the remaining key management requirements relating to: 1) time management, 2) resource allocation, and 3) assuring factory productivity and profitability through the assessment and implementation of new technology. These key requirements are conceptually described in sections relating to:

- o Integrated scheduling
- o Integrated resource allocation
- o Technology assessment/implementation.

Product Definition and Planning - The coalition envisioned that the merging of the design and manufacturing planning functions (Product Definition Planning) was essential to achieve integrated operations in the FoF. This integration was deemed necessary since all manufacturing begins with design (our common data base begins here) and a producible design is mandatory for reliable production and product quality. As a result, the merging of these activities are paramount for successful operations in the FoF and provide one of the most fruitful areas for reducing the time from customer order to product delivery.

The discussion of this key requirement in the SS document evolves around concepts for:

- o Interactive computer graphics for
  - Modeling
  - Simulation
  - Standard information exchange
- o The application of Group Technology
- o Automated Process Planning
- o A common data base

Product Assurance - Assurance of product quality will require control and coordination at all levels of the aerospace enterprise through 1995, since segments of the quality function are inherent in all phases of factory operations. Achievement of this objective will require the implementation of total quality assurance. The coalition established the following concepts centered around total quality assurance:

- o Design quality into the product - do not rely on the inspection and rejection of defective parts, do it right the first time
- o Improved inspection processes
- o Improved control of manufacturing processes
- o Integration of quality assurance information with all factory activities
- o On-line/real-time configuration management procedures.

Human Resource Management - The transition from the factory of today to the FoF was recognized by the coalition as a path that was bounded by technological as well as human relation pitfalls. In consequence, numerous concepts for enhancing Human Resource Management (HRM) in the FoF were developed. These concepts are built around the following HRM considerations:

- o Consideration of Human Resource requirements in long range strategic planning
- o Continuous monitoring of technological innovation to assess its impact on human resources at all levels of the organization - shop floor to front office
- o Developing strategies for training current personnel
- o Developing new policies for employees.

Materials Management - Material costs can represent 50% or more of total weapon system costs. As our aerospace system becomes more sophisticated and complex, material costs and the cost of maintaining inventories can reach astronomical levels. As a result, the coalition, in recognizing this situation, developed concepts for materials management to assure that the right materials, facilities, components or subcontracted assemblies are available: 1) at reasonable cost, 2) with the desired quality, 3) in the needed amount, 4) at the required time, and 5) where needed. To support this requiement, specific conepts were developed around:

- o Effective selection of vendors, suppliers and subcontractors
- o Near real-time communications with vendors, supplies and subcontractors

- o Advanced planning for material requirements
- o Control of materials inventory
- o Establishing production facilities with flexible equipment
- o Control and management of materials at the enterprise level.

Financial Management - Management of finance in the FoF will be as critical as in the Factory of Today. However, in the FoF financial emphasis must shift from profitability in the short run to: profitability in the long run and what resources must be expended to remain competitive. In addition, the theoretical framework of factory operations which forms the basis of our financial analysis techniques must be changed to meet actual operational conditions. This implies a shift from financial measurements based upon direct touch labor (now approximately 10% of our workforce) to financial measurements that reflect the time costs of people, operations, and processes required to produce the product.

To support this financial management approach, concepts were established to support the:

- o Accurate and timely collection, storage and manipulation of financial data
- o Accurate forecasting and estimating of financial trends
- o Development of tools and techniques for dynamic financial analysis
- o Improvement of general accounting procedures
- o Efficient financial measurement and analysis

3.2.3.2 Task B, Establish Factory of the Future Conceptual Framework (WBS 4.2.3.2)

The coalition prepared IDEFØ models of the "TO BE" Conceptual Framework which addressed the needs and improvement concepts identified in the Needs Analysis Document, System Requirements Document, and System Specification. These models were correlated with the existing ICAM Architectures (i.e., MFGØ, DESØ and QA/QCØ) in Section 6.0 of the Conceptual Framework document.

Initially, the coalition envisioned a set of detailed function models to describe the 1995 aerospace factory. This vision was not realized as the extensive scope of the Task B effort precluded the detailing originally envisioned. At the root of the problem was the generic nature of the functions and concepts, which, while ideal to form a basis for system design were not specific enough to permit a consistent viewpoint for detailed modeling below the second level.

To counteract this lack of a consistent viewpoint, the coalition attempted to model the FoF with different viewpoints as reflected by the seven needs categories, i.e., Information Resource Management, Product Assurance, etc. There is an extensive incomplete set of working IDEFØ models as a result. This approach was dropped when it became apparent that its time consuming, complex effort nature would prohibit completing the remaining task efforts. As a result of this uncompleted attempt at detailed modeling of the FoF, the coalition concluded that detailed models would be more appropriate when addressing specific factories vis-a-vis a generic factory. That is it would be easier to hold a consistent viewpoint for the FoF model of a Vought Aero Products Division or a GD/FW.

3.2.3.3 Analyze Factory Framework Centers and Subsystems Interactions (WBS 4.2.3.3)

The Conceptual Framework Document (MMR110512000), provides a detailed discussion on the Conceptual Framework the reader is referred to Volume II, Part 6 of the Final Technical Report.

In the Conceptual Framework Document, an approach for achieving computer-integrated manufacturing through the 1995 time frame is presented. First, the aerospace enterprise (factory) is presented as a total system, its goals are reviewed, its operating environment is discussed, its principles of operation are defined, its functions are described, and its major components are identified. Second, the major factory components are discussed from a physical view (people, production tools and equipment, facilities, and computer communication networks) and from a logical view (the enterprise common data base and the logical processes used to manipulate data/information). Major components of the FoF system were presented from a physical and logical view to:

- Curb the current practice of addressing the FoF in terms of specific applications (capabilities) e.g., MRP I and II, CAD/CAM, flexible machining, integrated sheet metal center, group technology, etc. These are but specific applications of technology and evolve over time, e.g., MRP I became MRP II, NC now consists of CNC and DNC, etc. The total view of the factory especially the FoF, is much larger than individual applications. It is the integration of these capabilities that determine the FoF system.

- Stress that the factory is more than an accumulation of physical resources used to produce product. These physical resources (people, product tools, equipment, and the information processing communication network) are vital - yet by themselves they cannot produce a product. It is human reasoning (logic) developing specific capabilities (procedures and techniques) to achieve a goal (e.g., build part, build assembly) and the transfer of these procedures and techniques as information to integrate the operations of the physical components that is the second essential element. This is the 95% of manufacturing operations related to data processing that is cited by authorities (e.g., James F. Lardner and Joseph Harrington, Jr.).

- o Shift the embedded traditional thought process of equating factory to shop floor. We, the coalition, want the factory to be thought of in terms of the total enterprise not the 5% represented by the shop floor.

Third, this document describes through 1995, an integrated aerospace enterprise composed of specific operation centers that support all the functions identified in the Conceptual Framework.

3.3 Establish Integrated Composite Center Conceptual Requirements Task C

The purpose of Task C was to establish preliminary designs and specifications for a computer-aided composites manufacturing center that integrates all activities required to produce composite components for small and large aircraft structures in an automated "paperless" factory. An outline of the WBS items used to accomplish Task C is shown in Figure 3-10.

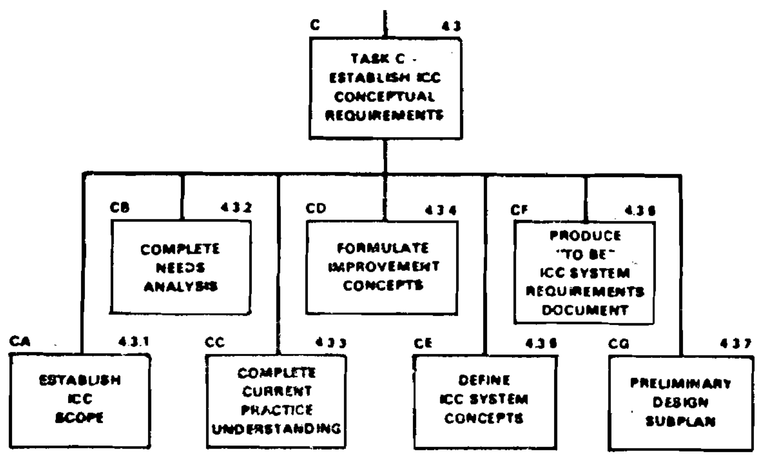


Figure 3-10. Task C Objectives by WBS

3.3.1 Establish Integrated Composites Center Scope (WBS 4.3.1)

The statement-of-work specified that the Contractor establish the scope of the Integrated Composites Center within the environment of current "AS IS" manufacturing. The scope was to include listings, together with textual descriptions, of all functions and information entities within the Architecture of Manufacturing whether performed by, interacting with, created by, or utilized by the Integrated Composites Center, (see Table 3-1 and 3-2).

The resulting scoping document was constructed to be in accordance with ICAM Documentation Standards and to reflect the areas of the function and information models of manufacturing referred to as MFG0 and MFG1 (see Table 3-3). The scope also contains the highest level function diagram (A-0) (see Figure 3-11) of the integrated composites purpose and viewpoint plus, at a minimum, the first level decomposition of the model (A-0).

These requirements were documented in the Scoping Document (SD), SD 110511000 which was submitted to the Air Force on 30 June 1982 and subsequently published. (Refer to Volume III, part 1 of the Final Technical Report).

The statement-of-work also required the Contractor to evaluate existing and future composites hardware production goals for both fighter and bomber/transport-type aircraft. Predictions were to be made of all possible aircraft structures in the 1981-1991 timeframe. Ranges of production were to be predicted and the kinds and numbers (quantities) of composite structures to be fabricated were to be estimated.

3.3.2 Establish Needs Analysis (WBS 4.3.2)

The Needs Analysis task was undertaken to form a baseline for the conceptual and preliminary designs of the Integrated Composites Center. Deficiencies were identified and methodology and technology improvements to correct those deficiencies were investigated. The coalition also:

- Identified the desired extent of the interaction of composites manufacturing with design engineering.
- Explored existing and desired performance measures of factory management level systems and shop floor control level processes.

3.3.2.1 Background

Structures produced from composite materials are part of virtually every modern military and commercial aircraft flying today. These materials have revolutionized the entire airframe industry and their use will continue to increase.

Table 3-1. Environment of ICC Conceptual Design

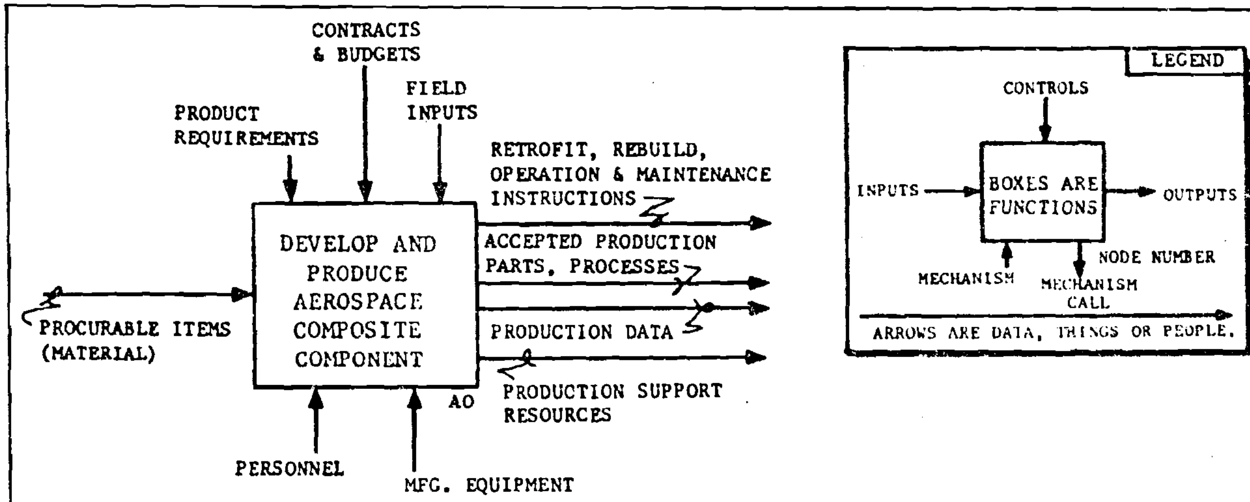
Design/Manufacturing Functions					
Design Application Area	Materials	Processes	Tooling	Techniques	Planning and Control
Fuselage	Type	Fabrication	Materials	Testing	Methods/Systems
Side Panels	Fiberglass	Hand Layup	Composites	Ultrasonic	Process Planning
Bulkheads	Kevlar	Robotics	Metallic	Radiographic	Production
Frames	Graphite(s)	Tape Layup	Ceramic	Visual	Ordering
Longerons	Boron	Spray Up	Elastomeric	Audio	Scheduling
Doors	Others	Pultrude	"Wash Out"		Shop Loading
		Blowmold	Salt Mandrels		Performance
Wing	Matrix	Automatic	Collapsible		Measurement
Covers	Polymide	Broadgoods	Rubber		Material Storage
Substructure	Epoxy	Layup	Bladder Bags		Inventory
Feathers	Metal				Management
Hard Points	Others	Transfer			Parts/Tool
		Hand	Control	Tracking	Tracking
Empennage	Form	Robotics	Inspection	Trend Analysis	Work-in-Process
Covers	Tape	Flip	Calibration	Material Review	Tracing
Substructure	Broadgoods	Flying Carpet	I&R Control	Board System	Inspection Records
Rudder	Filaments/	Vacuum		Config Mgmt	Testing Equipment
	Tows			Corrective	Quality
Design	Woven	Cure		Action System	Procedures
Conditions	Mat	Autoclave		Cost Analysis	Scrap/Rework
		Oven			Analysis
Temperatuare	Condition	Air	Scheduling		Test Inspection
Moisture			Rework		and Evaluation
Load	Prepreg	Assembly	Repair		Approach
Electrical	Dry	Bond	Inspection		Analysis
Thermal CDEFF	Material	Drill/Fasten			Management
Stiffness	Sampling	Inserts			Methods
Geometry	Procedures	Cocure			Variance Analysis
Maintainability	Techniques				Methods
Reliability	Trend Data	Equipment			Improvement
Mfg Cost	Equipment	Inspection			Numerical Control
OA	Location	Maintenance			Data
Specifications		Service			Process Software
		Calibration			Manufacturing/
					Design Cost
					Trade-Offs

Table 3-2. Physical Functions of the ICC

1.	Design composite parts
2.	Develop quality assurance plans for composites
3.	Develop and produce tooling for composites
4.	Receive and inspect incoming raw materials
5.	Receive and inspect detail parts (from other Centers)
6.	Clean and prepare detail parts
7.	Dispense raw materials
8.	Cut plies
9.	Kit plies
10.	Kit detail parts and plies
11.	Orient, position and stack plies
12.	Debulk laminate
13.	Inspect uncured laminate
14.	Form laminate
15.	Place laminate on curing tool
16.	Bag, leak check, and inspect
17.	Cure
18.	Trim and drill laminate
19.	Inspect laminate
20.	Prefit subassembly details
21.	Join laminates and details
22.	Inspect and prepare curing tools
23.	Inspect completed structures
24.	Rework and repair discrepant structures
25.	Move and store kits, parts and tools
26.	Initiate inspection records (for historical records and trend analysis)

Table 3-3. Integrated Composite Center Functions

Architecture Node	Function Title
MFG A-11	Manage Product
DES A1	Develop Conceptual Design
DES A2	Develop Preliminary Design
DES A3	Develop Detail Design
MFG A1	Plan For Manufacture
MFG A2	Make & Administer Schedules and Budgets
MFG A3	Plan Production
MFG A4	Provide Production Resources
MFG A5	Obtain Manufacturing Materials
MFG A6	Produce Product
QA A1	Develop Quality Requirements
QA A2	Prepare Quality Plan
QA A3	Provide QA/QC Resources
QA A4	Implement Quality Plan
QA A5	Evaluate QA/QC Effectiveness
MFG A-14	Provide For Product Logistics



PURPOSE: TO ESTABLISH AN UNDERSTANDING OF THE "AS IS" COMPOSITE MANUFACTURING ENVIRONMENT TO PROVIDE THE BASIS FOR IMPROVEMENT APPROACHES AND METHODS.

VIEWPOINT: COALITION TEAM FOR AEROSPACE COMPOSITE MANUFACTURING AND DESIGN.

NODE	TITLE	NUMBER
ICC/A-0	(a) THE INTEGRATED COMPOSITE CENTER	

Figure 3-11. ICC/A-0 Diagram

Despite their increased use, composite structures are still being produced in a very inefficient (labor-intensive) manner, particularly in such areas as laminating, bagging, trim-and-drilling, production flow, etc. Not only is this a major problem for current production programs but, as the rate and complexity of composites production increases, the requirement for automated production, planning and control, and quality assurance becomes critical.

3.3.2.2 Requirements

The task was to identify major needs (perceived deficiencies) that impacted the fabrication and subassembly of composites structures and could be alleviated through application of new technology or changes in operational methodology. These results would then be used to form a baseline for developing the conceptual and preliminary designs for the Integrated Composites Center. Additionally, the degree of design/manufacturing interaction was to be analyzed and recommendations made as to integration of these two functional activities. Performance measures for factory level planning, scheduling, controlling, QA/QC and shop floor control were to be investigated, analyzed and recommended.

Thus, the first step taken by the coalition was to identify the key areas needing improvement and the second step was to analyze these areas in terms of cost/performance and human factors. Next, the identified needs in the "AS IS" factory were prioritized by a subjective rating system as follows:

- Improved laminating techniques
- Improved bagging materials and techniques
- Improved "up front" design, manufacturing, QA interface
- Improved curing procedures
- Improved material and material forms
- Better tooling
- QA/QC, NDT improvements and enhancements
- Human factors
- Trim and drill enhancements
- Material handling, material kitting
- Manufacturing planning and control
- Shop floor control
- Integral structures
- Aumoated design tools.

These primary needs are discussed in the following paragraphs.

3.3.2.2.1 Improved Laminating Techniques

An immediate need in the aerospace community is to improve laminating techniques which are predominantly labor-intensive and time consuming. There were a few exceptions to this method where production facilities used tape-laying machines or industrial robots for laminating. However, even with

2

Despite their increased use, composite structures are still being produced in a very inefficient (labor-intensive) manner, particularly in such areas as laminating, bagging, trim-and-drilling, production flow, etc. Not only is this a major problem for current production programs but, as the rate and complexity of composites production increases, the requirement for automated production, planning and control, and quality assurance becomes critical.

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- o Manufacturing planning and control
- o Shop floor control
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These primary needs are discussed in the following paragraphs.

3.3.2.2.1 Improved Laminating Techniques

An immediate need in the aerospace community is to improve laminating techniques which are predominantly labor-intensive and time consuming. There were a few exceptions to this method where production facilities used tape-laying machines or industrial robots for laminating. However, even with these automated laminating techniques, the parts being fabricated were essentially flat or only slightly contoured, whereas the next generation of aircraft will use a larger percentage of laminates on complex curved structures, e.g., wings, fuselages and the entire empennage.

These more complex structures will require increasingly sophisticated methods of laminating. Automated machines must be able to dispense both narrow and wide tapes. A future laminating cell should be capable of automatically laminating any type or size of structure employing such mechanical devices as tape-laying robots, winding techniques, and advanced molding techniques such as pultrusion. Theoretically, this would remove the human element from the cell - a major savings in time and cost.

Debulking, another operation closely aligned with the lamination process, needs substantial improvement. Debulking is the process of densifying plies during layup. It is usually done by applying pressure to a stack of plies enclosed in a vacuum bag. In fabricating relatively thick laminates at the present time, as many as 10 to 15 debulk cycles are required resulting in a substantial cost increase.

A need to eliminate debulking for all flat laminates was identified to greatly reduce the number of cycles for complexly-contoured laminates. Thus, the need for the debulking process must be established. If there is a definite need for debulking, then improved debulking techniques must be developed to minimize the cost of this procedure.

3.3.2.2.2 Improved Bagging Materials and Techniques

Current bagging procedures are labor-intensive and require constant monitoring and checking. Two bagging methods are presently used: (1) a disposable nylon bag, and (2) a reusable rubber bag. These bags provide an air-tight membrane from which a vacuum can be pulled.

Disposable bags must be continually checked for leaks. They do not conform well to complex laminates. As a result, blown bags are common during the curing of complex laminates.

Reusable rubber bags can be recycled through a finite number of cure cycles before they degrade. They are tailored to conform to the configuration of the lamination. They are less prone to leaks and, as more pressure is applied in the autoclave, the bag seal becomes tighter which eliminates peel-back.

If the requirement to bag parts for curing continues, there will be a need to improve current bagging techniques. Reuseable rubber bags will speed the actual bagging process, allowing it to be automated. This will reduce bagging hours, the number of scrapped parts due to leaks and blown bags and will produce cost savings due to the lower life cycle costs of reusable bags.

3.3.2.2.3 Improved "Up Front" Design Manufacturing QA Interface

As much as 90% of the commitment of funds for new aircraft systems are made during the design phase of a new program. By the time production is initiated, tooling, manufacturing and facilities costs are locked in. To impact these costs, feasible design alternatives, manufacturing approaches and material systems will have to be evaluated at the conceptual stage.

This could be done by having accessibility to a "global" data bank of information containing a manufacturing cost/design guide, a structural composites fabrication guide and an advanced composites design guide. Analyses of this data would ensure that new programs take full advantage of the learning that has taken place on existing and prior programs as well as various advancements in research and development.

3.3.2.2.4 Improved Curing Procedures

Needs which require improvement in the area of component composite curing include:

- A method to monitor and control in-process anomalies. A feedback loop is needed to eliminate scrap due to bad cures and voids from the entrapment of gas bubbles.

- Development of an automatic autoclave loading system. This would reduce amounts tied-up in capital requirements, lower operating costs, and possibly permit recycling of perishables, i.e., nitrogen or hot air.

- A method of reducing total curing time, temperature and pressure. A possibility exists in improved, quick-cure resin systems as well as innovative curing techniques such as microwave and radio frequency.

3.3.2.2.5 Improved Material and Material Forms

Although there are risks associated with introducing new material systems into on-going production programs, the coalition tentatively established the requirements for composite materials as follows:

- Simple-to-process organic matrix resins
- Tougher matrix material with greater impact resistance
- More environmentally stable materials
- Moisture-resistant (250° - 300° F curing) tough resin systems for subsonic military aircraft
- Greater thermal stability for the 350° F cure system for fighter aircraft
- Tighter control of material tack
- Longer, or unlimited, out-time without refrigeration
- Increased testing and characterization of thermoplastics

- o Lower fiber and resin matrix costs
- o Higher temperature resin systems
- o Continued development of hybrid composites
- o Development of self-adhesive material systems
- o Continued investigation into radar-absorbing materials
- o Tighter control of resin/fiber content by the vendor
- o Development of an experimentally generated data base in composite materials maintainability and field repair
- o Continued work on "whisker" composites
- o Investigation into resins with thermal stability in the 350° - 500° F range with high strain-to-failure ratios, i.e., bismaleimides, polyimides, etc.
- o Investigation of methods to allow the aerospace community more control over all composite material processing. This might entail the industry becoming vertically integrated or the possible development of intermediaries to provide first and second-stage processing on material before it is passed on to the end-user.

At the present time, there is a pressing need to investigate the dichotomy that exists between maintaining the existing interindustry segregated structure and embracing a vertical integration structure. The following questions must be answered in deciding whether to integrate other related production operations into an existing corporate structure.

- o Can present facilities be used or are new facilities required?
- o Are there sufficient financial and capital resources available to either build or acquire existing companies?
- o What new management talents and technical skills are needed to integrate with minimum interruption?
- o Is there a way of increasing competition within today's traditional relationship?
- o If vertical integration occurs, will it result in the production of an excess quantity of goods which must be disposed?
- o How sensitive is the community to raw material processing?
- o Would regulations regarding monopolies and restraint of trade be a problem?

3.3.2.2.6 Better Tooling

Needs to improve composite tooling to meet future requirements and alleviate existing bottlenecks include:

- o Tooling that is durable, dimensionally stable, leak-proof and inexpensive

- o Tools "based" on mathematical models, in conjunction with CAD/CAM interface, to produce exact replicates

- o Tools designed to accommodate reusable bags which have built-in integral thermocouple sensors, integral venting, built-in dams and other required instrumentation

- o Tools with a surface finish that minimizes preparation time for layup and allows easy removal of the cured component

- o Enhanced tool repairability

- o Methods to automatically move, store and control tools based on their sequence of use.

3.3.2.2.7 QA/QC/NDT Improvements and Enhancements

The current approach to quality assurance/quality control and non-destructive testing is often redundant, time-consuming, labor-intensive and costly. The following problems are linked with QA/QC engineering and planning.

- o Not being able to collectively assess the effect of defects
- o Not being able to determine exactly what is critical to the structural integrity of the part or component
- o Not being able to relax the current requirement for 100% inspection
- o Not being able to relax the demand for perfect composite parts (never a requirement for metallic parts).

In their analyses, the coalition identified the following needs which were required to enhance inspection procedures.

- o Streamline the NDT process by developing statistical data analysis techniques based on destructive testing of scrap parts
- o Newer, quicker procedures to inspect the wing/fuselage interface, i.e., bolted joints in composite structures
- o Reduce dependence of human interpretation of x-rays through automated video-enhancement techniques
- o A computer-integrated ultrasonics inspection system.

3.3.2.2.8 Human Factors

The "AS IS" factory environment for composite fabrication is extremely labor-intensive except for those computer-driven systems which automatically cut prepreg broadgoods and the composite fabricators that employ automatic tape layers. One other exception is autoclave curing which is computer-controlled but manually loaded and monitored.

There is a need to overcome general personnel problems such as: low morale; falling productivity; negative job satisfaction; interpersonal conflicts; job stress and overlapping or duplication of effort. To improve the motivational goals of employees, the following suggestions were offered:

- Educating personnel to the effects of automation
- Developing positive programs to overcome the natural resistance to change
- Realistically defining goals and objectives of the organization and communicating them to all employees
- Establishing an effective recruiting, training, development program
- Constantly reaffirming the organization's objectives
- Continually evaluating the activities of the organization in relation to its people and the external environment.

3.3.2.2.9 Trim and Drill Enhancements

The current approach to trimming, drilling, countersinking and reaming is predominantly labor-oriented and physically hazardous. What is needed to enhance these operations is to:

- Reduce the number of detail parts by design
- Reduce the requirements for fasteners by using bonded joints
- Develop the proper equipment with the right speeds and feeds
- Reduce or eliminate inspection procedures
- Automate both drilling and trimming operations
- Fabricate parts "net" to reduce trimming
- Investigate new methods of cutting and trimming
- Cut-in or mold-in holes during lamination.

3.3.2.2.10 Material Handling Material Kitting

Because most of the work in material handling and material kitting is hand-labor, an integrated system that provides for the storage and transfer of all materials and tools used in the fabrication process is needed. Emphasis should be concentrated on developing:

- An effective autoclave loading and unloading system
- An automated storage and retrieval system for movement of prepreg material, in or out of the freezer
- A system to move, store and control the layup/bonding tools within the production center
- An effective means of moving large plies or parts in or out of the layup fixture
- A "hands-off" system to effectively conduct non-destructive evaluation when employing of x-ray or C-scan.

It is possible that this integrated material handling system could be married to a sophisticated kitting control system which would maintain the work-in-process inventory within the freezer.

3.3.2.2.11 Manufacturing Planning and Control

Since composite manufacturing is a flow process, it is incumbent on management to develop and implement realistic and cost-effective planning and control mechanisms. There is a pressing need for automated systems that could relieve the current or potentially "strained" production planning and control mechanisms. These systems should have the capability of:

- o Reducing the amount of paper generated in today's factory
- o Manloading the shop
- o Furnishing current composite work instructions, components and tools and be able to report shortages
- o Tracking work performed and identifying any anomalies
- o Providing schedules that detail arrival time, start time and completion dates of detail parts and subassemblies

3.3.2.2.12 Shop Floor Control

Current shop floor control systems can be summarized as factory-hour data collection and job tracking systems. Their inability to effectively control and plan the dynamic aspects of composites manufacturing is a major shortcoming. This shortcoming can be attributed to the following:

- o Current systems do not measure performance at a low enough level to be effective in planning the actual work content and flow time
- o The collected data is often not available in an accurate and timely manner
- o All of the necessary resources needed to produce composite parts are not controlled by the same system
- o The shop floor control systems are poorly integrated with the other factory systems
- o These systems do not provide a data base for storing and retrieving all of the production information needed and generated in the manufacturing process
- o Current systems are inadequate in terms of decision support information for production management
- o "AS IS" systems, because they are intended to support factory-wide operations, are difficult to change to support the unique needs of composites manufacturing
- o Despite the semiautomated production control systems in use, shop floor control is still extremely labor-intensive.

3.3.2.2.13 Integral Structures

The coalition found that current thinking on integral structures in the composite community is centered around two major ideas: 1) ways to reduce costs of composite parts, and 2) the development of innovative design concepts which can use composite materials. One of the most revolutionary aspects of composite manufacturing is the idea of building assemblies as opposed to building detail parts and subsequently assembling them.

However, to increase the rate production of large integral composite structures, technological improvements are needed in the following areas:

- o Cocuring of structural components with confidence
- o Rapid inspection of complex structures
- o Quickly, reliably, and inexpensively producing contoured and formed laminates
- o Repair and/or rework of integral structures to correct manufacturing defects and/or field damage
- o Designing and building foolproof tooling for cocured structures
- o Movement, storing, and curing of large complex structures
- o Production of flat laminates automatically
- o Formation of flat laminates
- o Production of structural stiffeners at rate
- o Effective integration of the design requirements with the automated production capability to achieve optimum performance/cost tradeoffs.

3.3.2.2.14 Automated Design Tools

At present, there needs to be an automated method of translating stress and loads data requirements into laminate designs. Because the manufacturing environment is evolving, cost drivers are constantly changing in priority and magnitude. As a result, the tendency is to design a part based upon current manufacturing techniques. This may be the single largest inhibitor to productivity improvements in composites manufacturing. From this, two major needs arise; 1) the need for a very close contact between composite part designers and manufacturing technologists, and 2) the need for an accurate, timely and easy-to-use means of accessing cost tradeoff data and analytical tools.

The ability to predicate designs on the "TO BE" versus "AS IS" manufacturing methods will be a major driver in the development and implementation of new technology. Five basic needs were found in the area of computer-aided design and its interaction with manufacturing and quality assurance.

- o There must be the capability to design a compound-contoured composite structure in three dimensions and automatically extract flat pattern layouts for each ply (automatically translate 3-D to 2-D).

- The 3-D design model must be directly translatable into quality assurance inspection criteria to support the automated and semiautomated inspection of composite structures and to aid in the objective disposition of non-conforming parts.
- The 3-D and 2-D design model must be directly translatable into control commands to drive automated manufacturing and inspection equipment such as robots, tape layers, cutters, nesting systems, ultrasonic and X-ray devices and material handling equipment.
- The design model and its parent models (for its next higher assembly) must be available for, and used to, design, coordinate, and manufacture all tooling and check fixtures for both the fabrication and assembly of composite structures and their installation on the aircraft.
- The design model and associated parts list data must be directly translated into manufacturing process plans with minimal human intervention.

3.3.2.3 Prioritized Needs

The needs, as described throughout this paragraph (3.3.2), are a synthesization of the needs of Vought, Northrop and General Dynamics. However, the prioritization of "needs" at any stage of a research and development program is extremely risky. To estimate potential benefits presumes that current real needs have been identified and conceptual solutions can be scheduled developed and implemented. It also presumes these solutions are correct and cost-effective.

There are two methods by which these needs could be prioritized. The first method was that the needs could be measured cordially, that is the product of the difference between two measurements. The second method would be to measure ordinally, that is to rank the needs on a purely subjective basis. The coalition used the subjective method because they felt that it yielded greater credibility, especially considering the "global" investigative approach which they took to arrive at the needs.

These prioritized needs and their rationale can be found in Section 3.0 of the Needs Analysis Document (NAD), NAD110511000 published 30 April 1982. Appendix A, Appendix B and Appendix C of this same document defines the Needs of Northrop, Vought and General Dynamics, respectively.

3.3.3 Complete Current Practice Understanding (WBS 4.3.3)

A System Environment Document (SED), SED110511000, (refer to Volume III) was prepared in accordance with paragraph 4.3.3 of the Statement-of-Work and submitted to the Air Force on 31 May 1982. This document described the activities and information necessary to produce composite airframe structures in the current aerospace environment.

The activity models developed by the coalition were based on factory-view models used by Northrop, Vought and General Dynamics. They reflect a compositing, synthesizing process from which generic activity models were developed.

Subsequent to developing these composite/generic models, the coalition visited the composite production facilities of McDonnell Douglas and Grumman. In general, Grumman's actual production operations differed slightly from those of the coalition's. Any significant differences were due largely to the manner in which the physical manufacturing functions were performed and in the naming of conventions for informational entities.

3.3.3.1 Facilities

At Vought and General Dynamics, facilities for composite structure production are an integral part of the total manufacturing plant. At Northrop, a single facility encompassing more than 320,000 square feet is dedicated to composite structure manufacturing. The floor layout of this Center is shown in Figure 3-12.

3.3.3.2 Manufacturing Process

Composite fabrication is characteristically a flow-type manufacturing process that produces a relatively small number of end-items to support assembly line requirements. At Northrop, for the F/A-18A aircraft, nearly 2,300 pounds of graphite are used in the 28 graphite composite subassemblies which consist of approximately 60 composite details.

Vought's manufacturing effort is primarily dedicated to fiberglass/epoxy composites, Kevlar and graphite composites in doors, elevators, rudders, spars, ribs, etc. on the Boeing 747, 757 and 767 programs.

The facilities at General Dynamics can produce approximately 800 pounds of composite laminates each month. Eighty percent of this capacity is achieved through automated tape laying machines; the remaining 20 percent is produced by hand. Primary constituents of these composite laminates include graphite and fiberglass fibers for the horizontal and vertical stabilizer skins of the F-16.

The fabrication of composite parts can be categorized into three basic types of end products-details, cocured assemblies, and mechanically fastened assemblies. Composite detail manufacturing differs from cocured and mechanically fastened assembly operations in that the end-item resulting from composite detail manufacturing becomes a component of the other two processes. The major difference between the cocured assembly operation and the mechanically fastened operation is that in the cocured process, hard parts are autoclaved cured to form a bonded subassembly. In the mechanically fastened process, "bonding" of parts is accomplished by manually fastening components.

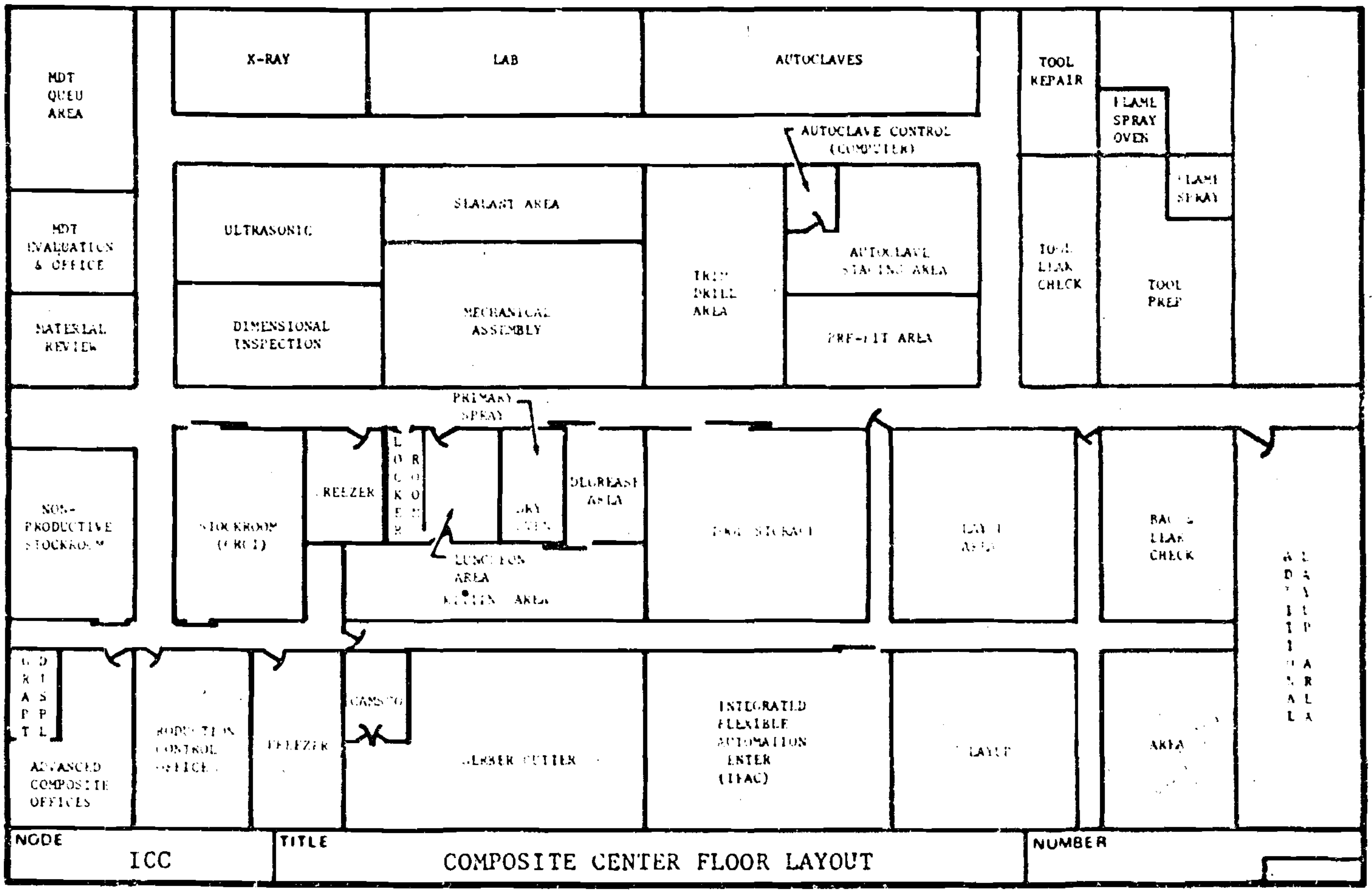


Figure 3-12. Composite Center Floor Layout

3.3.3.3 Materials

Prepreg material includes both unidirectional and woven material. The material could be tapes measuring as little as 3 inches in width or broadgoods measuring up to 60 inches. Vought and General Dynamics primarily use tapes; Northrop uses broadcloth.

The broadcloth is stored at 0°F. It is thawed for approximately 16 hours before use. It is cut on a Gerber table. Normally five layers of broadcloth are laid and cut simultaneously. Besides graphite, fiberglass and adhesive broadgoods are also cut by the Gerber. Two computer-controlled Gerber reciprocating knife cutters are used. Sufficient broadgoods are cut, kitted and stored to normally ensure the availability of five shipsets at all times.

The layup operations for detail parts and cocured assemblies entail the laying of the broadplies, ply-on-ply, onto the bonding tool for subsequent curing. Tape laying machines are used by General Dynamics and Vought; some tape laying is also done manually.

The layup is debulked every five plies to compact the ply layers and to eliminate airpockets. The bagged layup is checked for leaks at the autoclave. Once inside, thermocouple wires are attached for computer monitoring. After curing, the tools are removed from the autoclave, debagged, the part removed and the tool cleaned. After being inspected, the part is transported to the final assembly line stockroom.

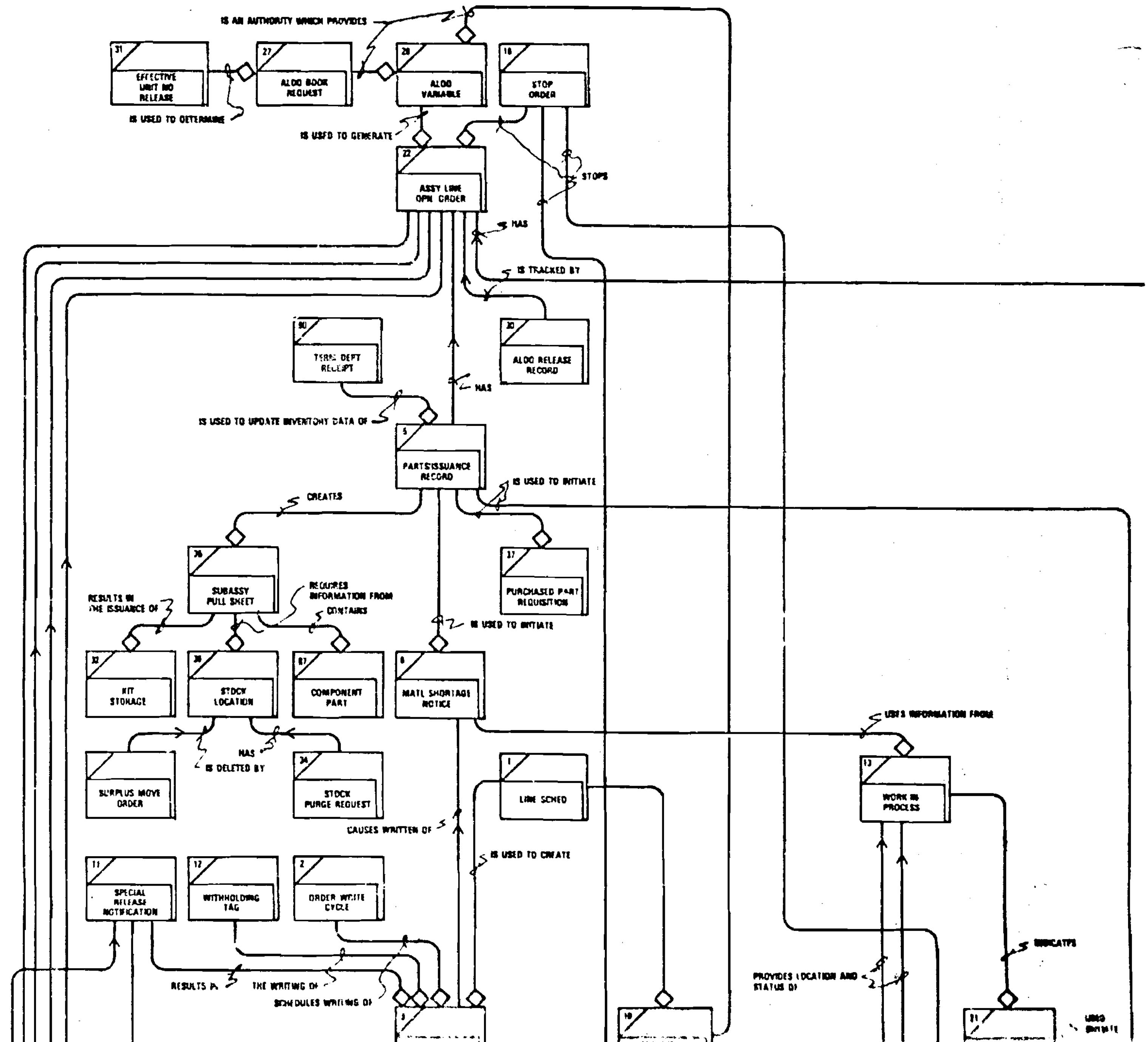
3.3.3.4 Information Model

Two aggregate diagrams representing the architecture of the "AS IS" information model developed for Task C are presented in Figure 3-13 and 3-14. The first figure describes the entity and relational classes primarily associated with preparing and issuing work authorization packages. The second figure describes the structure of information relative to the processes associated with composite parts fabrication. Taken together, the two figures represent the total entity and relational classes of the IDEF1 information model of Appendix A of the SED dated 31 May 1982.

3.3.3.5 IDEFØ Activity Model

The IDEFØ activity model represents the environment of aerospace composites manufacturing. It focuses on the recurring production of parts. However, it does not attempt to describe all of the functions and information necessary to produce composite parts.

As part of their analysis, the coalition reviewed the ICAM Architecture of Design and Manufacturing (DESØ and MFGØ) for their applicability to composites manufacturing. It was determined that these two architectures adequately reflected the functions and information which were needed to manufacture composite parts in the aerospace environment.


IS AN AUTHORITY WHICH PROVIDES
31
EFFECTIVE UNIT NO RELEASE
27
ALOD BOOK REQUEST
28
ALOD VARIABLE
18
STOP ORDER
IS USED TO DETERMINE
IS USED TO GENERATE
STOPS
22
ASSY LINE OPN ORDER
HAS
IS TRACKED BY
30
ALOD RELEASE RECORD
TERM DEPT RECEIPT
HAS
IS USED TO UPDATE INVENTORY DATA OF
5
PARTS ISSUANCE RECORD
IS USED TO INITIATE
CREATES
SUBASSY PULL SHEET
REQUIRES INFORMATION FROM
CONTAINS
RESULTS IN THE ISSUANCE OF
17
PURCHASED PART REQUISITION
IS USED TO INITIATE
KIT STORAGE
STOCK LOCATION
COMPONENT PART
8
MATL SHORTAGE NOTICE
USES INFORMATION FROM
HAS
IS DELETED BY
SURPLUS MOVE ORDER
24
STOCK PURGE REQUEST
1
LINE SCHED
13
WORK IN PROCESS
CAUSES WRITTEN OF
IS USED TO CREATE
11
SPECIAL RELEASE NOTIFICATION
12
WITHHOLDING TAG
2
ORDER WRITE CYCLE
INDICATES
PROVIDES LOCATION AND STATUS OF
RESULTS IN
THE WRITING OF
SCHEDULES WRITING OF
3
10
21

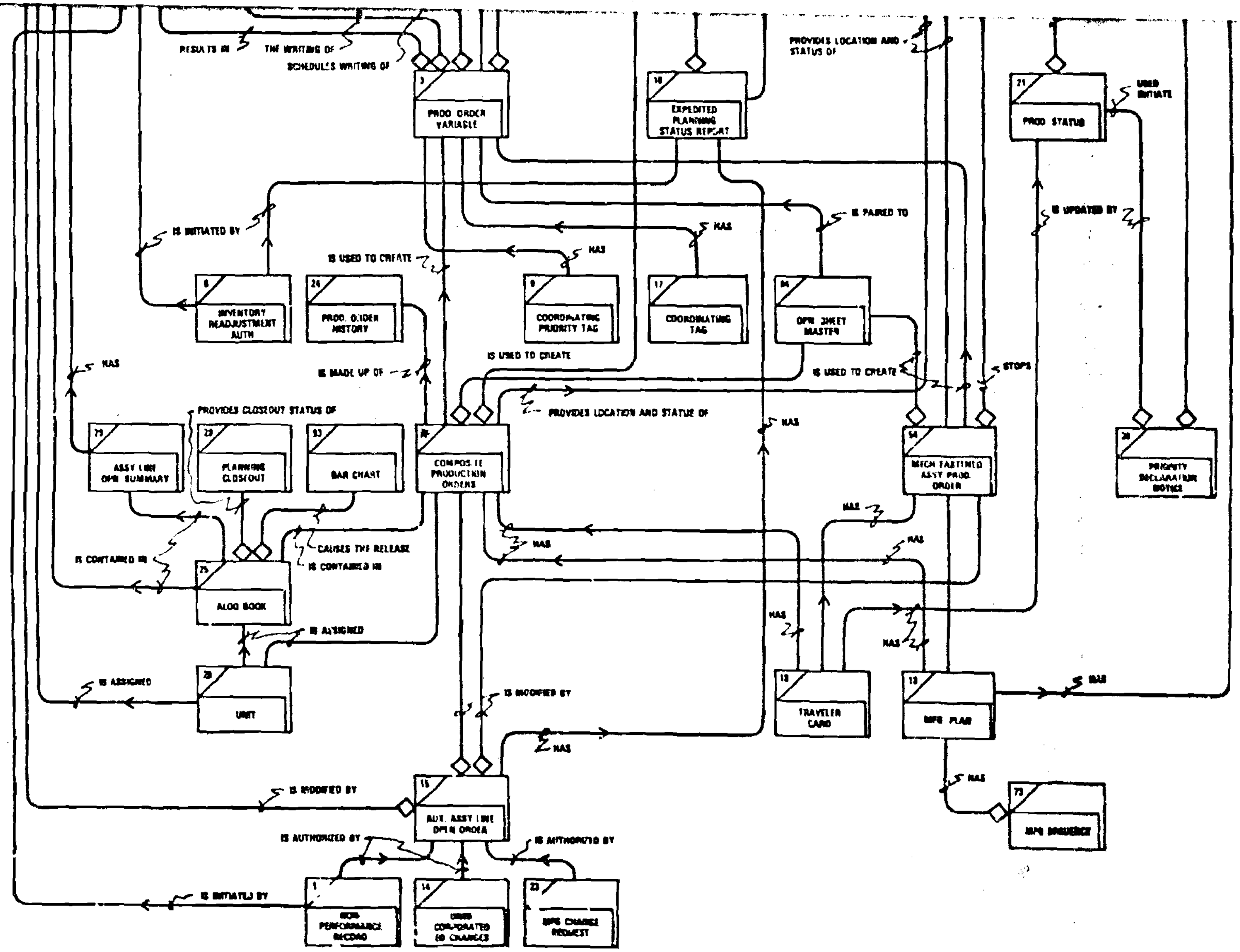
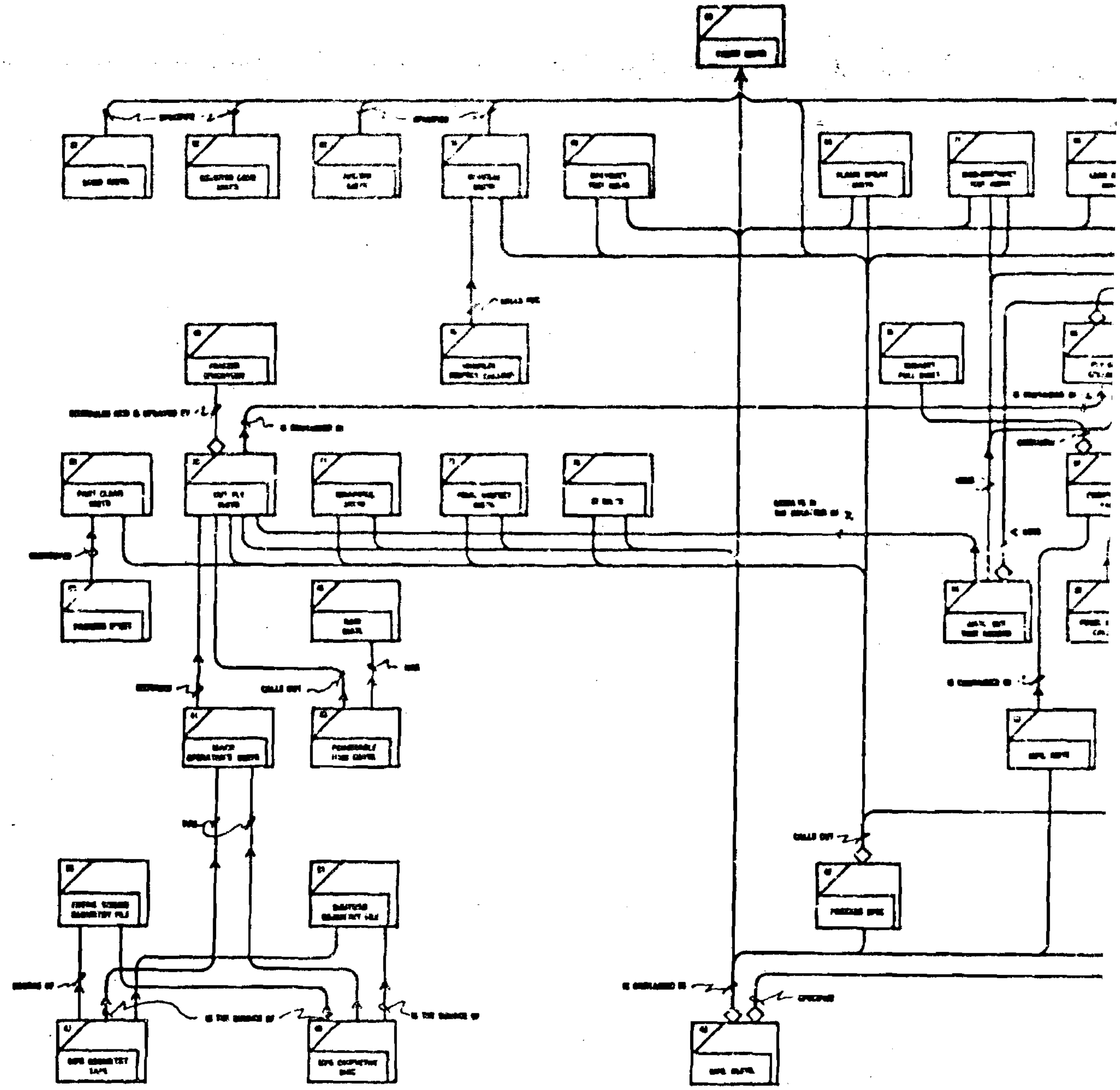


Figure 3-13. IDEF1 FEO: Work Package Control

3-48



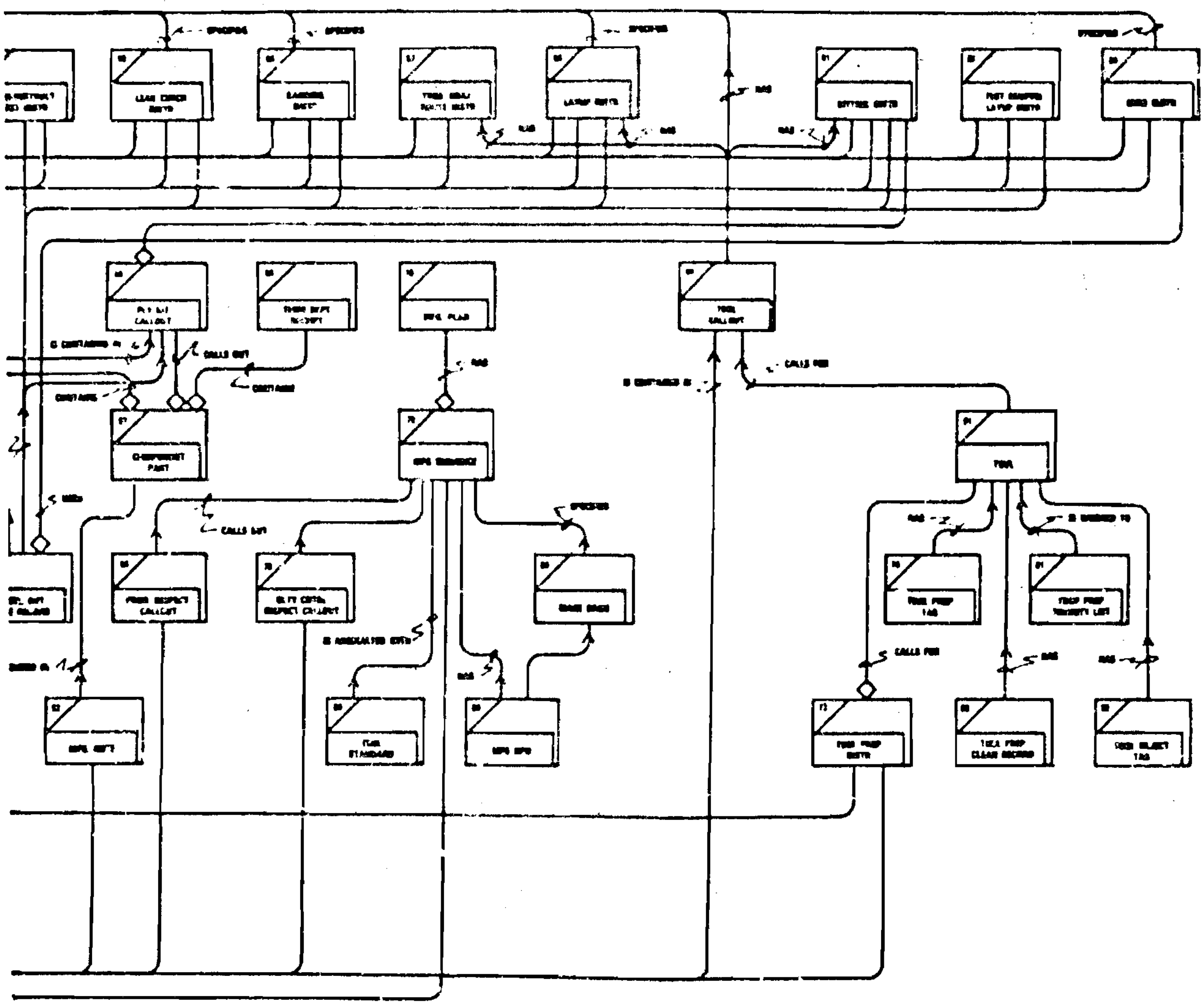


Figure 3-14. IDEF1 Information View: Composite Product Manufacturing

A complete, detailed discussion of the IDEF0 activity model with illustrations is available in the Systems Environment Document (SED110511000), (refer to Volume III, Parts 3A and 3B) which was submitted to the Air Force on 31 May 1982.

3.3.4 Task C, Formulate Improvement Concepts (WBS 4.3.4)

Using the dynamics model and simulation results established in the System Environment Document as a baseline, the coalition identified improvement opportunities for production methods now in practice. This analysis led to a verification of the needs identified in the Task C, Needs Analysis Document. Additional needs were identified during this study; they are defined specifically in the Systems Requirement Document (SRD), SRD110511000, submitted to the Air Force on 31 July 1982 (refer to Volume III, part 5).

These improvement concepts were largely conceptual in nature; nevertheless, they were used to guide the efforts of the program into areas of need which potentially offered the highest return on investment. Needs which evolved from the analysis completed in the Needs Analysis Document were validated in the System Requirements Document.

Requirements, as well as any associated technological voids, were cost-estimated and reranked, based on the availability of all resources, the projected cost savings and the subjective interpretation of all data. These concepts are examined further in paragraph 3.3.6 of this document.

3.3.5 Define Integrated Composites Center System Concepts (WBS 4.3.5)

Current practices in composites manufacturing were assessed by surveying the composite production facilities of Northrop Vought, General Dynamics, Grumman, McDonnell Douglas and Bell Helicopter.

In addition, equipment vendors were contacted and literature and specifications were reviewed to establish which needs could be satisfied by commercially available technologies and equipment. Because of the relative newness of high strength composites in airframe manufacturing and the comparatively low production volume and rates currently experienced in the aircraft industry for composite parts, it was discovered that large technology voids exist.

One area of particular interest to the coalition in their state-of-the-art investigation was the automated laminating cells at Northrop, Vought, General Dynamics, and Grumman. All these cells were developed under ManTech Production Integration contracts from the AFWAL/MLTN with the exception of the Vought system which was internally funded.

The findings of the state-of-the-art investigation were submitted to the ICAM PMO for review and comments under report number SAD110510000, State-of-the-Art Document, Task C, Integrated Composites Center Requirements and Design, dated May 1984 (refer to Volume III, Part 4).

3.3.6 Produce "TO-BE" Integrated Composites Center Systems Requirements Document (WBS 4.3.6)

The SRD (refer to Volume III, Part 5) document describes requirements which must be fulfilled by the "TO BE" ICC system. Northrop, Vought and General Dynamics each individually analyzed the requirements needed to improve their specific composite production systems and defined the requirements and technologies needed to elevate composites manufacturing into the 1990 time-frame. Various composite manufacturing operations were grouped or clustered to visualize how they would interrelate with the entire fabrication or subassembly process. While this method might not be applicable to all manufacturing firms, it did serve as a coalition standard in the transitioning process. The coalition then established certain ground rules on which to base their assumptions of composites manufacturing in the 1990 time-frame - they are as follows:

- The trend to automation will accelerate in all phases of composite fabrication and subassembly
- The elimination of autoclaves, ovens or similar heat/pressure vessels is highly unlikely
- The major composite material will be graphite/epoxy with 250° and 350°F cure profiles
- Nondestructive Evaluation will not disappear nor be greatly reduced, especially for primary structures
- The demand for composites will continue to grow at an anticipated 35% annual rate
- Since the aerospace community is committed to composites, the necessary resources will be provided to develop the logical primary and support systems.

Using these groundrules as a baseline, the following paragraphs describe the specific performance requirements to be satisfied by the "TO BE" system.

3.3.6.1 Composite Laminating Requirements

Present automated laminating techniques are for parts that are essentially flat or only slightly contoured. The next-generation aircraft will require composite materials for major secondary and primary structures such as wings, fuselages and the entire empennage structure. This will require more advanced methods of laminating capable of forming complex contours and of dispensing both narrow and wide tapes.

Laminating is the process by which a composite detail part or structural component is fabricated/formed by placing or building-up one lamina (a single ply or fiber) superimposed on another until the required density is achieved. Composite laminating requirements include:

- o The capability to accommodate various composite material forms
- o The ability to employ these forms to fabricate components without size constraints, notwithstanding design, curing and nondestructive evaluation
- o An automated storage and retrieval mechanism to be used in conjunction with a full-up, real-time inventory management system for both raw materials and work-in-process.
- o Automatic, computer driven cutting of composite materials that consists of one or all of the following methods:

  Laser
  Waterjet
  Gerber reciprocating knife
  Steel rule dies

- o Sophisticated nesting, identification/labeling and kitting systems to maximize efficiency and cost-effectiveness of these automated cutting techniques
- o Low cost, automated, in-process inspection procedures, such as on-line video inspection based on some type of accept-reject criteria.

3.3.6.2 Filament Winding

Filament winding is a laminating technique now being given considerable study. Its most common applications at present are in conical/cylindrical configurations and for rotor blades and driveshafts of roto-wing aircraft. The following requirements are needed to enhance present filament winding capability.

- o Provide complex shape capability in mandrel design and fabrication
- o Solidify machine motion technology (hydraulic versus electronics)
- o Increase microprocessor capabilities to handle a myriad of winding motions
- o Control with diagnostic capabilities
- o Remote location programming
- o Acceleration of hybridization of composites

- o Design of parts that can be filament wound.

3.3.6.3 Pultrusion

Pultrusion is a quasi-laminating procedure which is the composite equivalent of the metallic extrusion process. This process is presently best suited for producing low-cost, constant, cross-section structural shapes. To expand the role of pultrusion in manufacturing, the following requirements must be fulfilled:

- o Standardization of structural shapes and stiffening elements
- o The capability to "pull" and cure concave/convex shapes with and without constant cross-sections
- o The acceptance of random fiber location within the cured component.

3.3.6.4 Braiding

Braiding is a laminating technique which had its foundation in the textile industry. The requirements to enhance this process are:

- o Better materials in terms of consistent braid patterns and control of fibers to prohibit twisting
- o Non-tacking prepreg tows
- o Wet resin/fiber braiding.

3.3.6.5 Centrifugal Casting

Centrifugal Casting is used to fabricate cylindrical shapes. These are molding techniques that could lend themselves to the production of aerospace-quality components, depending on the structural integrity which must be maintained and include:

- o Injection molding
- o Compression molding
- o Resin transfer molding.

3.3.6.6 Requirements for Composite Bagging

Bagging is required when the cure of the laminate takes pla[illegible] an autoclave or oven. The entire bagging process is extremely la[illegible] intensive, especially when disposable bags are used. The requirements for bagging during autoclave operations in the "TO BE" Integrated Composites Center include:

- Elimination of disposable bags

- Development of low-cost, reusable bags that are impervious to matrix volatiles

- Elimination or reduction of inspection "buy-offs"

- Design of precut consummables

- Automation of entire bagging operation

- Development of specialized bagging procedures to achieve consistency

3.3.6.7 Requirements for the Design/Manufacturing/Quality Assurance Interface

Design analysis must be made early enough in the product life cycle to ensure that new programs take full advantage of existing production programs and various research and development efforts which have been undertaken between production programs. This requirement could be satisfied by automated data collection techniques and reporting methods and a means of effectively accessing and retrieving this information. Specific system requirements would include:

- An increase in the use of computer-aided design (CAD) and computer-aided manufacturing (CAM)

- The integration of CAD/CAM and computer-aided testing and inspection

- Use of computer graphics to design aircraft, provide 3-D modeling, on-screen testing and video flight simulation

- The development of a common data pool directly accessible to structural analysts, design engineers, NC programmers, inspection and cost analysts

- The use of solid modeling to identify such variables as volume and center of gravity

- The standardization and computerization of process planning with built-in quality control manufacturing engineering data check

- Hardware/software compatibility with defined procedures

- Group technology support system structure

- Integrated communications flow between design, manufacturing and quality.

3.3.6.8 System Requirements for Composite Curing

To affect the transition from the "AS IS" to the "TO BE" condition, the following requirements for both the autoclave and non-autoclave cures must be met.

- Implement a cost-effective, computerized method to monitor and control the curing process with the ability to identify in-process anomalies and a feedback loop for corrective action
- Reduce the number of cure profiles by 50%
- Gang-load discrete curing fixtures on a "master" fixture in the autoclave staging area
- Recycle the heat and pressure that is vented off upon completion of the cure to reduce recurring costs of autoclave operation
- Develop a queuing system for autoclave staging and loading
- Increase use and acceptance of cocuring
- Develop a method for lamina/resin material characterization coupled with time/pressure/temperature sensing during curing.

Other curing techniques will require:

- For thermal expansion molding, tighter control of the pressure between the rubber mandrels, more accurate calculation of thermal expansion, and tighter control of temperature profile
- For matched metal dies, more cost-effective dies with faster heat-up and cool-down capabilities
- For pultrusion, since the requirement is for dies configured to produce pultrusions of varying cross-sections, a "staged" curing system may be needed
- For oven curing, the requirements are the same as for the autoclave.

3.3.6.9 Requirements for Composite Materials

To reduce the risks associated with introducing new composite materials into ongoing production programs, the requirements are:

- Future organic matrix resins that are easier to process
- Tougher Matrix material with greater resistance to impact

- o More environmental stability, i.e., low moisture absorption
- o Moisture resistant (300° to 350° curing) tough resin for subsonic military transports
- o Greater thermal stability for the 350°F cure system for fighter aircraft
- o Tighter control of material tack
- o Longer or unlimited out-time; no refrigeration required
- o Increased testing and characterization of thermoplastics
- o Low fiber and resin matrix costs
- o Higher temperature resin system
- o Continued development of hybrid composites and self-adhesive material system
- o Continued investigation into radar-absorbing materials
- o Tighter control of resin/fiber content by vendor
- o Development of an experimentally generated data base on composite material maintainability and field repair
- o Continued work on whisker composites
- o Investigations into resins with thermal stability in the 350° to 500°F range with high strain-to-failure ratios
- o In-house composite prepreg manufacturing facilities.

3.1.6.10 Requirements for Composite Tooling

System requirements for tooling of composite materials, predicated on the autoclave as the curing medium, include:

- o Development of new materials or the improvement of existing materials that will produce tools that are durable, (minimum of 500 cure cycles) dimensionally stable, leak-proof and inexpensive
- o Tools able to accommodate reusable bags with instrumentation to identify in-process curing anomalies
- o Tools with a surface finish that would require minimum time in the tool preparation station and allow for easy removal of the cured component

- Tools which can be easily repaired and maintained
- Tools derived from mathematical models used in conjunction with CAD/CAM to produce exact replicates
- Jacking studs used in the tool substructure to provide adjustable contours in the curing fixture
- Tools with locating devices to ensure the correct location of the laminate and to prevent laminate movement.

Table 3-3 illustrates several tooling material comparisons.

3.3.6.11 System Requirements for Quality Assurance and Control

The system requirements for quality assurance/quality control in the "TO BE" environment are:

- Gradual elimination of human interpretation of the various NDT evaluation techniques
- Elimination of in-process quality inspection in layup by establishing repeatability and standardization through automation
- On-line/real-time video inspection techniques
- Use of non-film radiography
- Digital computer enhancements of radiographs and fluoroscopic techniques
- Procedures to inspect the wing/fuselage interface
- Ability to inspect and prove the acceptability of parts prior to cure
- The use of 3-D, photogrammetric or other orthographic video inspection techniques to match the completed component with a computergraphic representation of the engineering design
- Emphasis on video inspection techniques
- Development of Mil-Standards for composite materials.

3.3.6.12 System Requirements for Human Factors

The system requirements for Human Factors in the "TO BE" Integrated Composite Center are:

- Adequate professional development for both managers and non-managers

Table 3.4 Tooling Material Comparisons

Material	Advantages	Disadvantages
Cast Ceramic	o Very stable o Can be used for self-heating tools	o Incompatible thermal expansion o Model and splash required o Chips easily o Slow heat-up rate, unless self-heated o Difficult to drill after being cast
Silicone Rubber	o Limited shape restrictions o Transmits pressure readily o Cheap for duplicate tooling	o Pressure hard to control o Loses dimensional stability with repeated use o Model needed/design critical o Not for skins
Steel	o Dimensionally stable with temperature excursion o Compatible coefficent of thermal expansion o Mold surface obtained directly from NC program o Provides hard surface, damage tolerant o Can be brake formed	o High tool weight o Slow machining o Slow heatup rate
Iron or Nickel (Electroform)	o Compatible thermal expansion o Good heat-up rate o Dimensionally stable o Hard jig pick-up points	o Expensive o Build plaster model to obtain contour o Lack of plating capacity of the tool manufactures
High-Temp Gr/Epoxy	o Good heat-up rate o Rapid tool fabrication o Dimensional stable for cures up to 250° o Tooling hard points provided o Compatible thermal expansion	o Tool degrades at 350° cure cycles o Durability problem o Requires plaster model

- o Increased participation in the decision-making process
- o Positive reinforcement programs to overcome resistance to change
- o Increased commitment to timely dissemination of information
- o Incorporating key principles of quality circles, quality of work life and participative management into the factory
- o Development of an attitude change by management acknowledging that today's workforce is more sophisticated and better educated than previous generations
- o Development of reward systems placing emphasis on long-range strategic planning
- o An all-encompassing program to develop the computer literacy of both managers and non-managers
- o Training in new composite systems via the computer or other state-of-the-art equipment.

3.3.6.13 Requirements for Trimming and Drilling of Composites

The system requirements for the trim and drill module in the "TO BE" Integrated Composites Center are::

- o To train composite structures designers to employ the unique aero-elastic properties of composite materials and actually design to reduce the number of detail parts
- o To reduce the number of fasteners by developing confidence in bonded joints
- o To introduce automation into the drilling and trimming operations
- o To fabricate laminates to their "net" configuration
- o To implement cutting tool and coolant technology to avoid short tool life, delaminations and heat build-up
- o To automate in-process inspection procedures
- o To develop low-cost trim and drill fixtures
- o To implement advanced optical control of waterjet cutting systems.

3.3.6.14 System Requirements for Material Handling/Kitting

The future requirement for material handling/kitting is for a computer controlled, integrated handling system that provides for the tracking, storage and transfer of the composite material and related consumables as well as for the layup tools/bonding fixtures used in the fabrication process. This would encompass:

- A low-cost, effective autoclave/oven loading and unloading system
- An automated storage and retrieval system to move prepreg material, kitted or not, in and out of the freezer
- A means for quickly moving kitted material to the layup area
- Automated techniques to move and control the layup/bonding fixtures within the production center
- A cost-effective technique to move large plies or parts either into, or out of, the layup fixture
- Material handling systems to provide for a "hands off" approach to NDE using x-ray and C-scan techniques
- Integration of the material handling system with the shop floor control system to maintain and control work-in-process inventory.

3.3.6.15 Requirements for a Manufacturing Planning and Control System

The following requirements must be implemented in the "TO BE" Manufacturing Planning and Control System:

- A system to keep production cycles at optimum, i.e., maximize use of scarce resources
- Provision for a reduction in lead times
- Furnishing correct composite work instructions packages via sequential 3-D models in CRTs
- Greater flexibility in information gathering, digesting, and dissemination to reduce the amount of paper generated in composite production
- Provide real time status of planning versus actuals with inventory control (both raw material and work-in-process) to maintain production schedules and reduce inventory costs

- Standardized production plans that correctly reflect shop floor fabrication procedures
- Establish a data management structure
- Real-time status reporting on composite facility capability, machine status, load status for support products and non conformance trends.

3.3.6.16 Requirements for a Composites Shop Floor Control System

The composites center must be organized in a hierarchical manner by standardizing detail designs and developing computer aids for manufacturing planning and related systems. The typical levels of hierarchy are:

- Center
- Cell
- Station
- Process
- Operation.

This hierarchy must stress flexibility to allow the shop floor control system to function properly and to evolve toward the automated systems and equipment being introduced.

3.3.6.17 Inventory Management

The inventory management component of the ICC will have to effectively interface with purchasing and finance for information storage, transfer and retrieval. It must maintain inventory levels consistent with production requirements and must monitor and maintain the storage location of the material. The invoiced cost of materials must be tracked, requisitions issued and spoilage information recorded and reported.

3.3.6.18 Requirements Generation and Order Writing

In the ICC, order writing and requirements generation are needed to plan the sequence of production orders from start to completion. Gross requirements are planned from three months to a year in advance of actual release of orders to the composites center. Net requirements are the gross requirements after being adjusted for scrapped or lost parts or last minute needs. This activity must be able to calculate what parts are needed, when they are needed, how many are needed and what account they should be charged to.

3.3.6.19 Work-In-Process Control

The work-in-process control will influence the flow of production orders through the various work stations to ensure that schedules are met. This function will also control the allocation of resources to ensure that they are expended efficiently. The work-in process control must meet the following requirements:

- The work must be controlled at each level of the hierarchy
- Production orders and rework orders must be scheduled and controlled based on priority, need date and resource use
- The workload must be effectively planned at each node of the hierarchy to optimize performance
- Resources must be available at each production step
- Information must be available to determine the schedule and completion status of each production order
- The system must manage and control the allocation of all ICC resources
- The system must requisition raw materials, move orders to the material handling system and maintain an inventory of all production items.

3.3.6.20 Personnel Management

The ICC shop floor control system must maintain the following personnel parameters:

- Available manpower
- Proficiency skill levels
- Training requirements
- Quality performance
- Job classifications.

3.3.6.21 Tool Management

The ICC shop floor control system must monitor and maintain the following information on contract tools:

- Current location and job number

- o Rework status (estimated completion date)
- o Engineering change level incorporated in tool
- o Tool capabilities
- o Physical characteristics
- o Autoclave history (number of cure cycles undergone estimated remaining cure cycles)
- o Cure profile class (for gang loading)
- o Quality history
- o Number and serial of duplicate tools or potential substitute tools.

3.3.6.22 Facilities Management

The ICC shop floor control system will have to monitor and control the maintenance of the physical plant, services and equipment. Unplanned and unscheduled outages of vital facilities and equipment must be minimized. When they occur, Facilities Management must provide contingency plans so as not to interrupt the workflow.

3.3.6.23 Quality Assurance Management

To reduce the cost and time requirements of quality functions without reducing credibility, the QA inspection functions must be integrated with the overall ICC production process. The system must monitor and control the allocation of resources, workmanship, conformance to design and the assignment of work to the Quality Control inspection stations and the Materials Review Board.

3.3.6.24 Queue Management

Queues will be necessary in the FoF to maintain a smooth work flow and minimize unplanned shortages or outages. Queues are desirable to take advantage of specific high cost resources such as autoclaves and high volume resources such as automated ply cutting. The major requirement of the Queue Management system is to balance schedule requirements. The following queues will be managed within the ICC:

- o Shop load queue
- o Kitted ply queue
- o Kitted part queue

- o Work-in-process queue
- o Autoclave queue
- o Tool maintenance queue
- o Inspection queue
- o Materials handling queue.

3.3.6.25 <u>Information Management</u>

Data handling and information processing are integral parts of all functions within the ICC. The following are specific requirements which must be satisfied:

- o Data that is easy to store and retrieve through automated methods
- o Access to information on a need-to-know basis
- o Data that is related in meaningful ways to avoid the necessity for interpretations and assumptions
- o Data that is accurate and timely
- o Checks to preclude unauthorized access and to update information
- o A response time for data entry and information within acceptable tolerances

3.3.6.26 <u>Contingency Management</u>

A major element in the effective control of the ICC is the ability to plan the workload and ensure that the plan is carried out. The following requirements exist for contingency planning and crisis management:

- o Shop load forecasting with a variable time horizon, with a variable workload, and with variable resource levels
- o Resource requirements forecasting
- o Risk projections
- o Estimated completion dates
- o Determination of slack or overloaded resources
- o Critical path determination using actual or simulated workloads.

3.3.6.27 Integration Management

Perhaps the largest contribution the shop floor control system can make to the ICC is integrating the various subsystems into a unified system to meet schedule and cost targets. The requirement must be satisfied to establish a common data base structure that integrates and shares all common information, including integration with the management information data base. Also, all production and support system information must be channeled into this common data base.

3.3.6.28 System Requirements for Integral Structures

Adopting integral structure composite technology in the aerospace environment would provide substantial cost and weight savings in future aircraft. The requirements for accelerating this technology into a production mode are:

- A sophisticated, cost-effective technology to layup integral structures
- Characterization of mandrel technology to enhance ease of removal
- Procedures and tools to NDE the completed cure structure
- Promote curing mediums other than autoclave
- Develop in-the-field repair and inspection procedures that are reliable and repeatable
- Reduce risks involved in fabrication, bagging and cocure of the stiffeners and skins where faulty layup techniques are involved
- Develop material handling systems to move large structures
- Re-evaluate final assembly procedures to provide for the acceptance of large structures thus replacing many individual components.

3.3.6.29 System Requirements of Automated Design Tools

System requirements for automated design tools would be:

- Enhancements in computer-aided design
- On-screen testing
- Models for predicting fatigue and damage growth behavior in the computer software
- Increased programming and a power base to simulate flight on the CRT

- Use of computer graphics to move away from wire-mesh images into more realistic representations of solid objects

- Establishment of an industry-wide structural composite data pool available to design, engineering and cost.

3.3.6.30 Estimated Cost and Benefits

Projections of the estimated cost and benefits of a fully developed Integrated Composites Center are discussed in paragraphs 3.2 and 3.3 of the Systems Requirement Document which was submitted to the Air Force on 31 July 1982. These estimated costs imply that all system requirements have been identified and correctly defined. However, as in all research work, the data is always suspect and subject to continual scrutinizing and interpretations. It should be noted that while a firm at the beginning of its composite programming may be able to achieve considerable savings, another company, well into its program, would probably realize lesser savings.

3.3.6.31 Requirements Prioritization

There are two basic techniques used to prioritize or rank the requirements discussed in this report. The first method assumes that the requirements can be measured carninally, or that measurements can be made which are numerically significant. The second approach is that they can be ranked ordinally. This latter approach means only that the requirements can be ranked based purely on a subjective determination on satisfying a single requirement. For this report, the system requirements were ranked using a combination of both approaches. The systems were ranked sequentially as follows:

- Composite Shop Floor Control System

- Advancements in Quality Control of Composites

- Composites: Manufacturing Planning and Control

- Composite Materials

- Tooling for Complete Material Fabrication

- Integrally Stiffened Composite Structures

- Composite Bagging Advancements

- Composite Laminating

- Enhancements in the Design/Manufacturing Interface

- Design "Tools" for Composites

- Human Factors.

3.3.6.32 Appendices

Appendices A, B and C of the Systems Requirement Document of 31 July 1982 describes in depth the advancement in the control and production of composite parts by Northrop, Vought and General Dynamics. Each of these Appendices provides views of the System Requirements as seen by each coalition member.

3.3.7 Preliminary Design Subplan (WBS 4.3.7)

Task E of the Integrated Composites Center, Preliminary Design, outlines three major areas of focus which were incorporated into the System Specification which was submitted to the Air Force for approval on 30 November 1982. The Preliminary Design Subplan also updated the Master Plan and Schedule for each milestone phase, task, and event.

The first area of focus of the Preliminary Design Subplan addressed general information including approved identification, nomenclature, authorized abbreviations and purpose of the System Specification. A summary of the existing system describing its purpose and function was also provided. This data supported and enhanced the System Specification.

The second area of focus provided a compilation of applicable documents which included previously developed documentation relating to this project, relevant documentation covering related projects and standards or specifications required to understand, support and augment the System Specification. Terms and abbreviations indigenous to the System Specification were listed and defined.

The third area was the crux of the System Specification. It provided a narrative and technical delineation of the system specifications required to accomplish the transition from the "AS IS" to the "TO BE" (generation +1) for composite manufacturing.

3.3.8 Task E, Produce Preliminary Design (WBS 4.3.8)

Based upon the requirements developed during the Base Program and documented in the SRD, Task E the Preliminary Design (Phase III, Option 2) of an ICC was awarded. Figure 3-15 provides an outline of WBS items used to accomplish this task. This design included shop floor subsystems, planning and control subsystems and a Management Information System. The subsystem modules developed as part of the IPS, HCMM AND IDSS projects were included in the ICC design as well as the QA/QC results of Task D.

Three site-specific Preliminary Designs were developed by Northrop, Vought and General Dynamics. These designs were oriented toward fighter and bomber/transport aircraft. Also, a Preliminary Design of a generic ICC was developed by the coalition. This generic ICC, as developed, would be able to produce components for both fighter and bomber/transport aircraft.

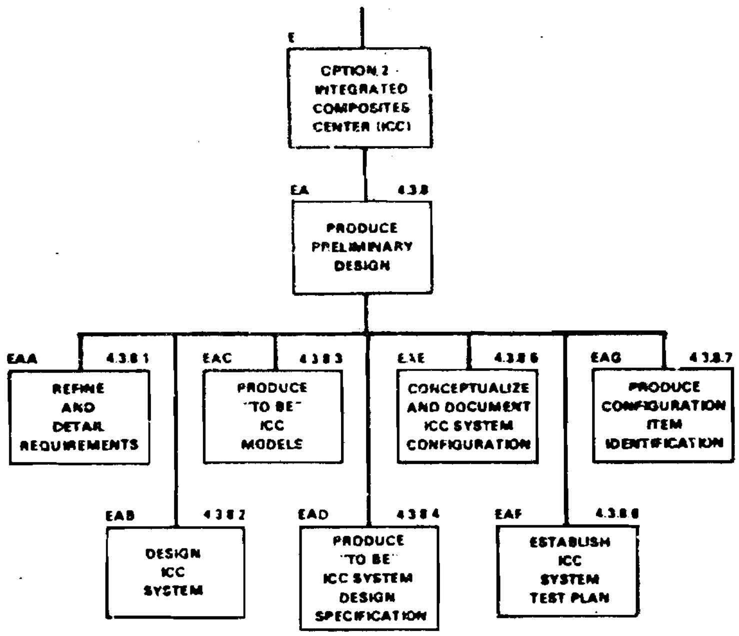


Figure 3-15 Task E Objectives by WBS

Technology transfer and portability were key design considerations. Each of the four preliminary designs included system test plans and an estimate of the size of parts, part types and production rates which could be expected to be produced by these "TO BE" centers.

3.3.8.1 <u>Refine and Detail Requirements (WBS 4.3.8.1)</u>

The results of this task were described in the System Specification Document (SS 110511000) on 30 November 1982 (refer to Volume III, Part 6). Its purpose was: to detail the system requirements to the maximum extent possible; to assure the reliability and validity of the requirements; and to promote understanding between the user and the contractor before initiating system design. This system specification provided for the manufacture of aerospace composite detail parts and subassemblies.

3.3.8.1.1 <u>Overview of Generic System Specifications</u> - The following is a broad overview of the major characteristics of the "To Be" Integrated Composites Center (ICC). The ICC must schedule and control the fabrication and subassembly of structurally acceptable composite components for both fighter-type and transport-type aircraft. For fighter-type aircraft, this means achieving an estimated production rate of 14 to 20 aircraft per month, with between 1,500 and 3,000 pounds of flyaway composite material on each aircraft. This translates into 10 to 50 percent of the airframe weight, which is sufficient to meet existing requirements and future projections. For transport-type aircraft, the production rate is estimated at between 3 and 5 aircraft per month with 5,000 to 15,000 pounds of composite material for each structural airframe.

However, the ICC may have to process an additional 20% of material to compensate for scheduled and unscheduled over allocation of material that occurs during the various stages of the fabrication and subassembly process. The size of structures that the ICC must accommodate will range from doors and panels for fighters to wing and empennage components for transport-type aircraft. They may be large flat laminates or small subassemblies with convoluting lines and surfaces.

The ICC must have the ability to laminate these structures using technologies that employ both broadgoods and tape-laying manufacturing approaches. The laminating cell will employ automated material-cutting techniques, as well as filament-winding capabilities, some pultruding of constant cross-section shapes, and limited injection-molding capabilities for nonstructural clips and brackets. There will be a flat laminating module for actual layup or preplying for subsequent forming and ply deposition techniques using both robotics and composite technicians. Modules for filament winding, pultrusion and injection molding will be present in the laminating cell.

All primary structures will be bagged and cured in an autoclave. Secondary structures may be vacuum bagged and cured in an oven or autoclave. Specialized curing vessels such as presses or mated dies will also be available.

A cell will be available for the trimming and drilling operations employing the latest equipment such as robots, waterjet cutters and cutting tool technology. Trimming and drilling is one of the more physically demanding, hazardous, and repetitive operations associated with composite fabrication and subassembly. Any contribution made by this cell in reducing the amount of human interface will be translated into less stringent OSHA requirements and improved safety performance. With proper design and manufacturing interface, the dependence on the cell could be reduced by laying up laminates in near net shapes and molding-in holes.

Permeating all of these physical processes will be checks made by the quality control cell to ensure that the structural integrity of the composite component is maintained. This would include, but not be limited to, initial receiving and inspection on-line, in-process inspection techniques, and state-of-the-art nondestructive evaluation and inspection procedures (C-scan, nonfilm radiography, etc.). All would be computer controlled with respect to part movement and testing procedures. Computer interpretation of test results would establish accept/reject criteria. Every attempt will be made within the Integrated Composites Center to minimize the impact (and thus the cost) of quality control through the use of statistics and the development of production processes that maintain product consistency.

Within the ICC, there will be cells specifically dedicated: to subassembly (the joining of composite details with core, stiffeners, or metallic details); to the reworking of cured laminates or subassemblies that have not met specifications; and to tooling preparation, maintenance and minor repair. Given the type of activities indigenous to each of these cells, and operating under the most optimistic of scenarios, it is still likely that these cells will be labor-intensive.

Tools, materials and composite components will move within the center via the automated material-handling system. This system, as well as the activities or physical processes that occur in each of the cells, will be directed by the ICC management system. The system will cost-effectively manage all resources required to manufacture composite components.

3.3.8.1.2 Northrop's Integrated Composites Center - At this stage of development, Northrop's "TO BE" Integrated Composites Center is a logical construct of interrelated subsystems. It will be a largely autonomous operation within the overall framework of Northrop's factory environment. Its operation will be coordinated to optimize the overall factory production capability. Many factory functions, not unique to composites manufacturing, but common to each of the subassembly and/or fabrication centers, will be relegated to factory level systems. This will allow the ICC to specialize in specific production requirements.

Because the ICC is seen as a "new" subsystem within a relatively "old" factory system, it is probable that the ICC design will require performance standards that existing factory level systems cannot adequately support. In these cases, specific performance parameters will be established.

In order to achieve its ICC goals, Northrop has chosen to include the production of both large and small aircraft components within its ICC. Its design will be based upon both the F-18A and F-20 production requirements but will also include production of a large, transport-type aircraft components within its requirements envelope.

Figure 3-16 shows the major components of Northrop's Integrated Composite Center. For a complete discussion of Northrop's future plans in developing its ICC, refer to Appendix A, of Task C, ICC Requirements and Design System Specification Document (SS110511000) which was submitted to the Air Force on 30 November 1982.

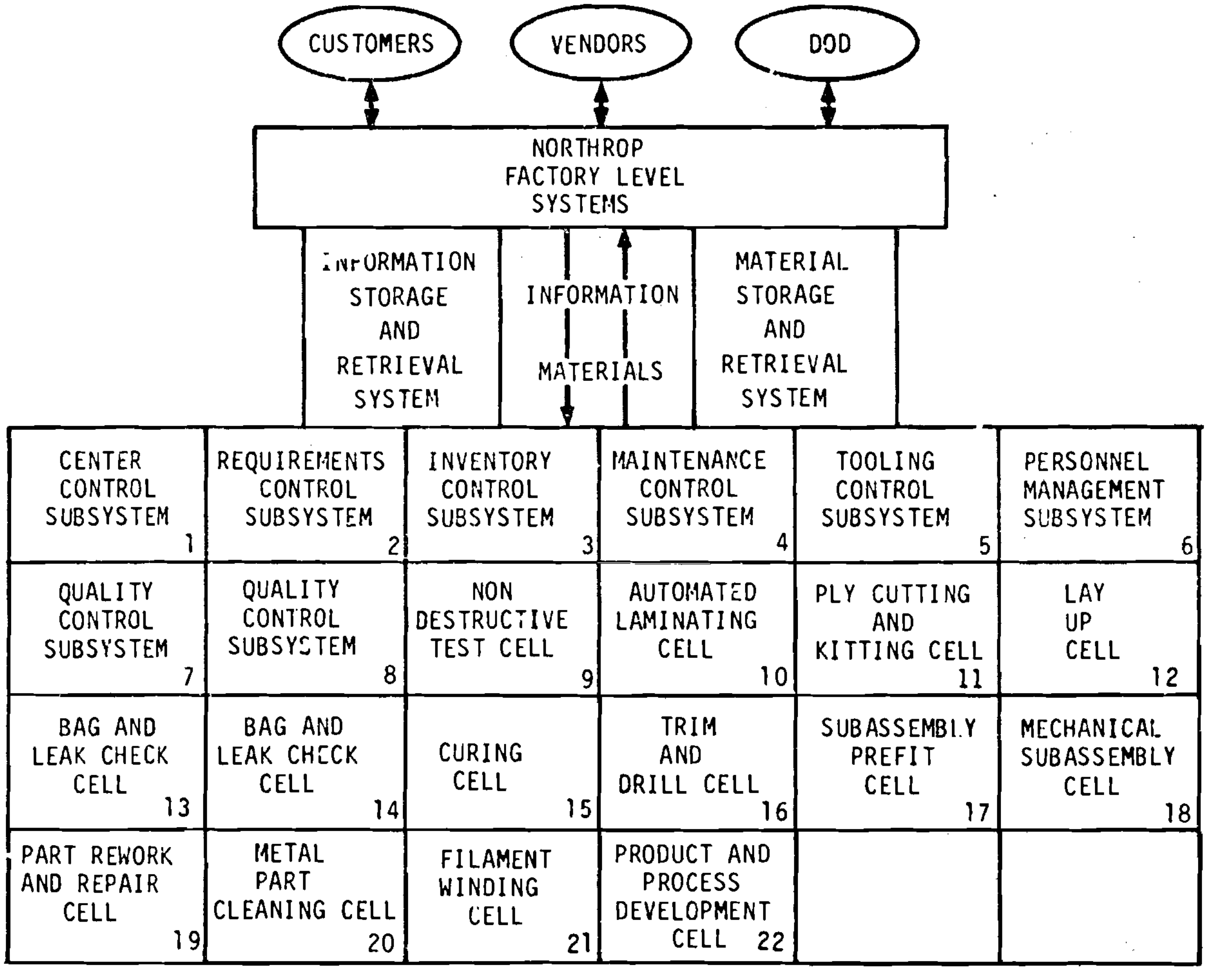


Figure 3-16. Northrop's Integrated Composites Center

3.3.8.1.3 Vought's Integrated Composites Center Preliminary Design - Based on the Systems Requirement Document, Vought designed a specialized production system and physical center for the production of composite parts and subassemblies. This system and center will be used as the basis for developing Vought's ICC.

When developing the strategy for the factory level system framework and its tie with the center, it must be understood that most functions of manufacturing will not change. What will change is the manner in which manufacturing operations are planned and conducted, and possibly the sequence in which they are accomplished. Some ingredients required in the successful development of the ICC will be: Group Technology, Direct Numerical Control, Robots, CAD/CAM and the use of such leading edge technologies as Generative Process Planning and 3-D Solid Geometric Modeling.

At the present time, Vought is committed to the production of large aircraft and helicopter composite components under existing contracts. The systems and facilities currently in place will be used as a basis for developing Vought's "TO BE" system. These facilities such as the Integrated Process System (Figure 3-17) will provide the basis for the automated laminating cell and the three autoclave systems presently in place will be used as the thermal cycling cell. The central factory level Manufacturing Control System will provide the basis for the Shop Floor Control and Planning Control systems.

Figure 3-18, the Integrated Composite Center interface, depicts the interactions with the Production Control Center and Data Management and Manufacturing Control Center as well as between the various cells within the ICC.

For a complete discussion of Vought's plans for the development of its ICC, refer to Appendix B of Task C, ICC Requirements and Design System Specification Document (SS 110511000) which was submitted to the Air Force on 30 November 1982.

3.3.8.1.4 General Dynamics Integrated Composites Center Preliminary Design - The General Dynamics model of the ICC provides the manufacturing capability for the production of advanced thermoset and thermoplastic composite structures. The center is arranged in a cellular configuration using highly automated and totally integrated systems. This cellular configuration lends itself to a high degree of system flexibility to facilitate system integration and implementation efforts. Figure 3-19 depicts a preliminary all arrangement for this center.

At the present time, existing floor space and facility layout are major limiting factors at General Dynamics. It is not certain whether a major arrangement of the facility would be cost effective.

There are also several technological voids such as limited cart maneuverability and floor guide paths to direct the carts which must be

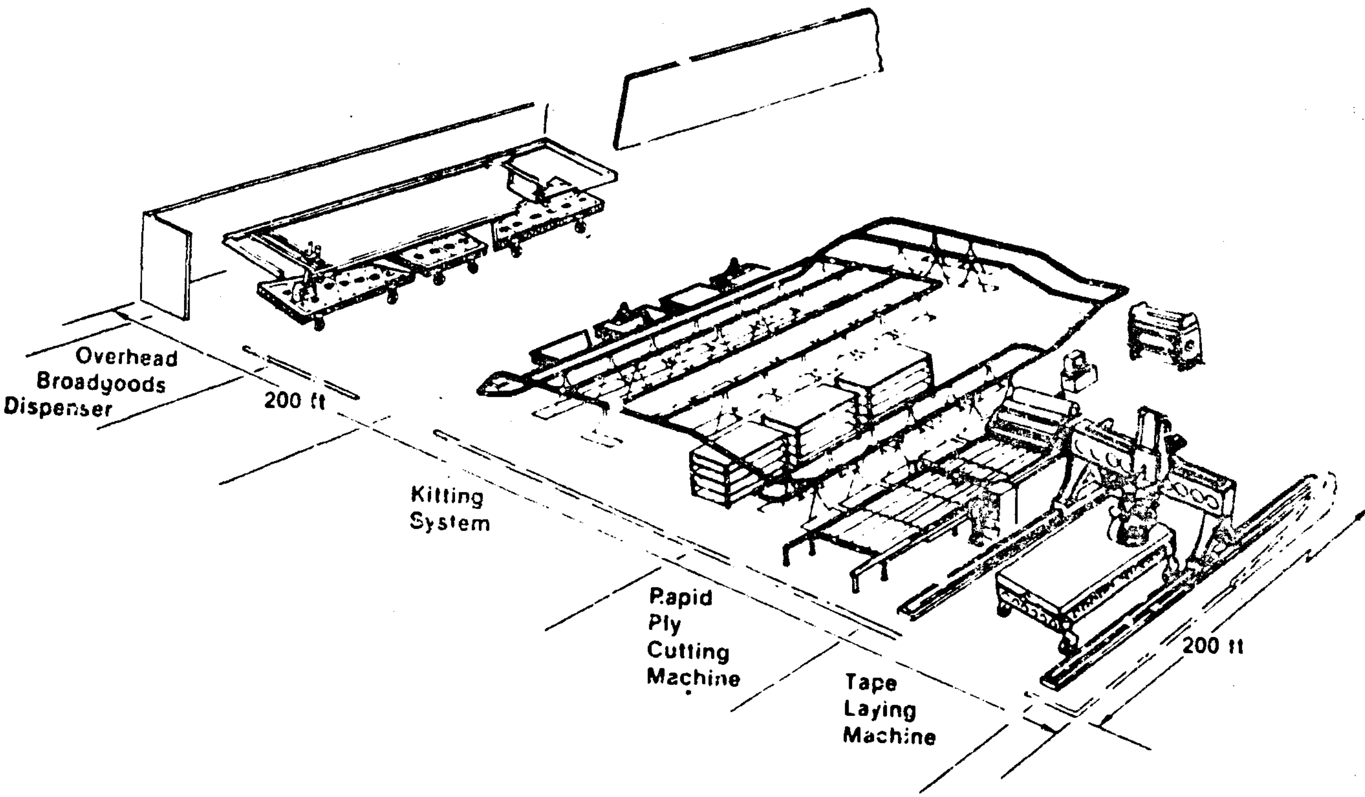


Figure 3-17. Integrated Processing System

PRODUCE COMPOSITE STRUCTURES

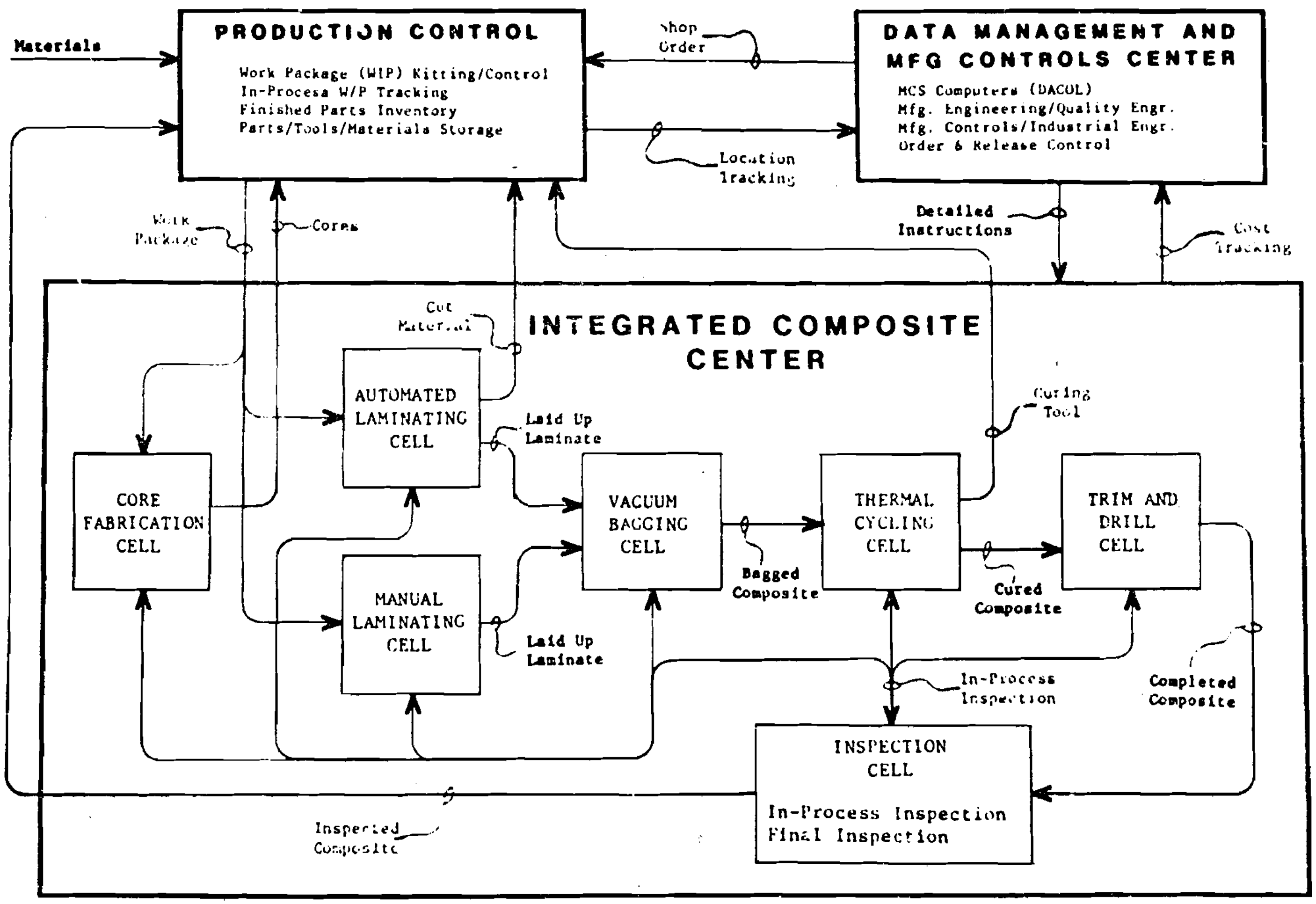


Figure 3-18. Integrated Composite Center Interface

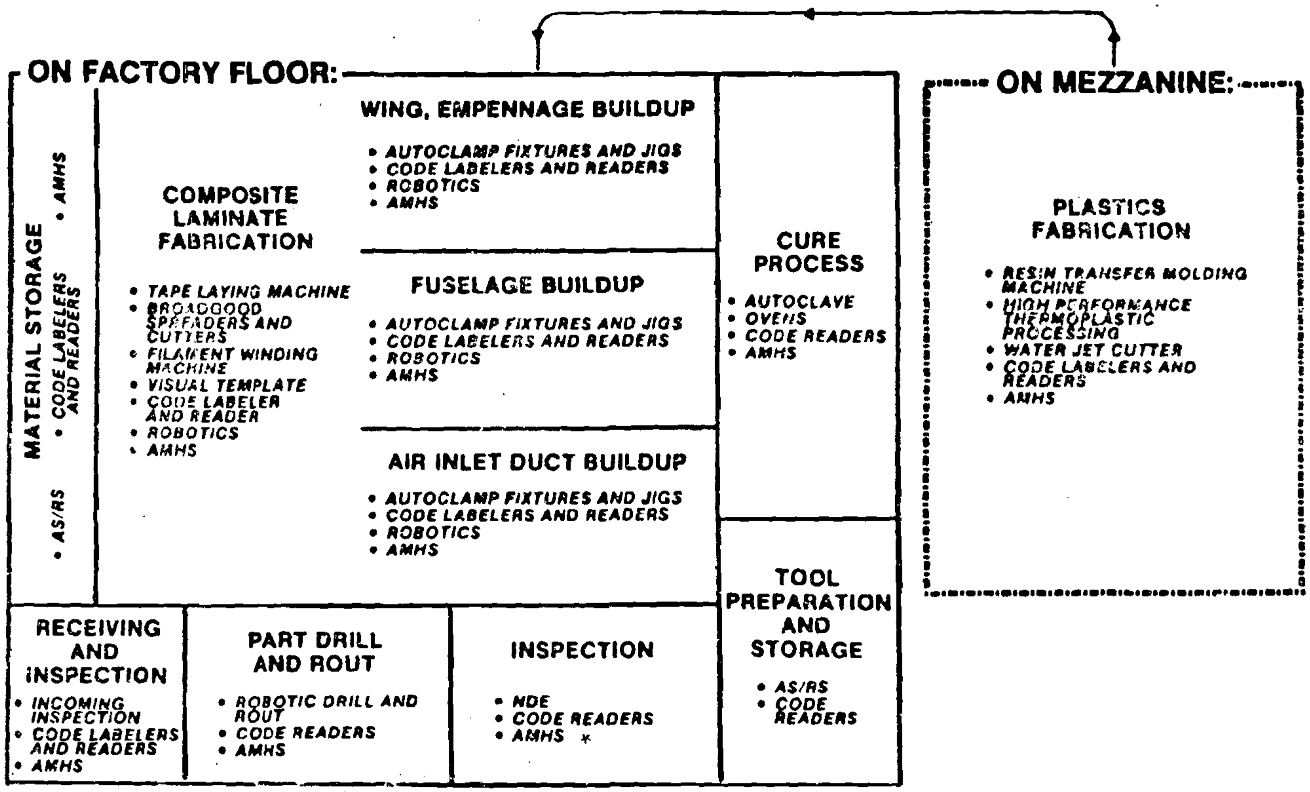


Figure 3-19. Preliminary Cell Arrangement of Integrated Composites Center

resolved. Other voids are in the area of Quality Assurance to develop visual, tactile and thermal sensors to monitor the manufacturing processes.

Other problem areas which must be resolved before General Dynamics can complete its ICC modeling are:

- Sensing/scanning devices and chemical characterization techniques to reduce mechanical testing requirements

- Methods to obtain processing viscosities to be used in plastics fabrication

- Improvements in tape-laying methods on concave/convex surfaces and to dispense different materials from the same tape-laying machine

- More research and development is needed in the cure processing of advanced nonmetallic materials such as thermoset and thermoplastic materials.

For a complete discussion of General Dynamics ICC development model, refer to Appendix C of Task C, ICC Requirements and Design System Specification Document (SS 110511000), which was submitted to the Air Force on 30 November 1982.

3.3.8.2 Design Integrated Composite Center System (WBS 4.3.8.2)

The System Specification prepared by the coalition outlined seven major sections which were subsequently incorporated into the SDS.

It is obvious that composite structures are still being produced in a very inefficient (labor-intensive) manner. The industry is still in the early stages of designing a "TO BE" integrated Factory of the Future relative to automated production, production planning and associated material and component flow through the shop.

As the rate and complexity of composites production increases, the requirements for automated production and planning becomes critical. The transition into composites will mandate the reduction and eventually the elimination of hand-labor and semiautomated techniques as they become less efficient due to size limitations, production rates, quality problems and cost consideration.

The System Design Specification (SDS), SDS110511000, dated 28 February 1983, (refer to Volume III, Part 7), preliminary concepts were the result of analysis performed for the SRD, the feedback from the System Requirement Review (SRR) and the elaboration of those requirements presented in the System Specification. The SDS addressed how each requirement of the SS will be satisfied.

The major system requirements of the SSD have been transformed into individual Configuration Items (CIs) representing both cells and systems indigenous to the ICC. These CIs, which must be fully developed and exploited to conceptually satisfy the system requirements, are:

- o Composite Laminating Cell
- o Composite Bagging Cell
- o Composite Curing Cell
- o Composite Trim and Drill Cell
- o Composite Test and Inspection Cell
- o Composite Subassembly Cell
- o Composite Rework Cell
- o Tool Maintenance Handling System
- o Material Handling System
- o Design/Develop Composite Structure
- o Composite Center Management System

These cells and systems and their functions are specifically described in Section 3.0 of the SDS document of 28 February 1983.

3.3.8.2.1 ICC Overview - The ICC must schedule and control the fabrication and subassembly of structurally acceptable composite components for both fighter and transport-type aircraft. The size of the structures will range from doors and panels for fighters to wing and empennage components for transport-type aircraft. They may be large flat laminates or small subassemblies with convoluting surfaces.

The center will laminate these structures using technologies that employ both broadgoods and tape-laying approaches. The laminating cell will employ: automated material-cutting techniques; filament-winding capabilities; protruding of constant cross-section shapes, and injection-molding capabilities for structural clips and brackets. There will be a flat, laminating module for actual part layup or preplying for subsequent forming, and ply disposition techniques using both robotics and composite technologies. Primary structures will be bagged and cured in an autoclave while secondary structures may be vacuum bagged and cured in an oven or autoclave. Specialized curing vessels such as presses or mated machined metal dies will be available as required.

A trimming and drilling cell using the latest equipment (robots and waterjet cutters) and cutting tool technology will be included. With proper design/manufacturing interface, the dependence on the cell could be reduced by laying up laminates net and molding-in holes.

The test and inspection cell will make checks to ensure that the structural integrity of composite components are maintained. This includes initial receiving and inspection, on-line in-process inspection techniques, and the latest in nondestructive evaluation and inspection procedures (C-scan, nonfilm radiography, etc.). All processes would be computer controlled and include computer interpretation of test results to establish acceptance or rejection. Every attempt will be made within the Integrated Composites Center to minimize the impact (and thus the cost) of quality control through the use of statistics, and the development of production processes that maintain product consistency.

Within ICC will be cells specifically dedicated to subassembly; to the reworking of cured laminates or subassemblies that do not meet specifications; and to tooling preparation, maintenance and minor repair. Given the type of activities indigenous to each of these cells, it is likely that they will be labor-intensive.

Tools, materials and composite components will move within the center via the automated material-handling system. This system, as well as the activities or physical processes that occur in each of the cells, will be directed by the ICC management system. This system will manage all resources required to manufacture composite components.

The major benefits derived from the implementation of the Integrated Composites Center are two-fold. The first will be the optimum use of scarce resources in terms of facilities, labor, capital equipment, raw materials and management acumen to thwart the law of diminishing marginal returns. The second will be the production of composite structures that are cost competitive in terms of acquisition and life-cycle costs. Figure 3-20 shows a generic conceptualization of an ICC exhibiting the major Configuration Items.

- <u>Physical Interfaces</u> - The physical interfaces between the Integrated Composites Center and the factory level systems are shown in Figure 3-21. As can be seen from this diagram, all physical items are transported by the intra/intercenter materials handling system. In a union shop, this division of labor may be mandatory in the current environment.

3.3.8.3 <u>Produce "TO-BE" Integrated Composite Center Models (WBS 4.3.8.3)</u>

Figure 3-22 shows an IDEF activity model of the Integrated Composites Center. This diagram shows the interrelationships among the eleven configuration items which make up the ICC as described in paragraph 3.3.8.2. Of special interest in this model are the complex interrelationships among the Manage function, the Test and Inspection function, and the Move and Store function. It is because of these interactions that materials, parts and tools are not shown "flowing" from one physical process to another.

3.3.8.3.1 <u>Northrop's Integrated Composites Center</u> - The following paragraphs describe the System Design Specification for Northrop's "TO BE" Integrated Composites Center system.

The ICC will be a largely autonomous operation within the overall framework of Northrop's factory environment. It will be oriented toward the specific functions and operations necessary to produce composite structures. Many factory functions not unique to composites manufacturing, but common to

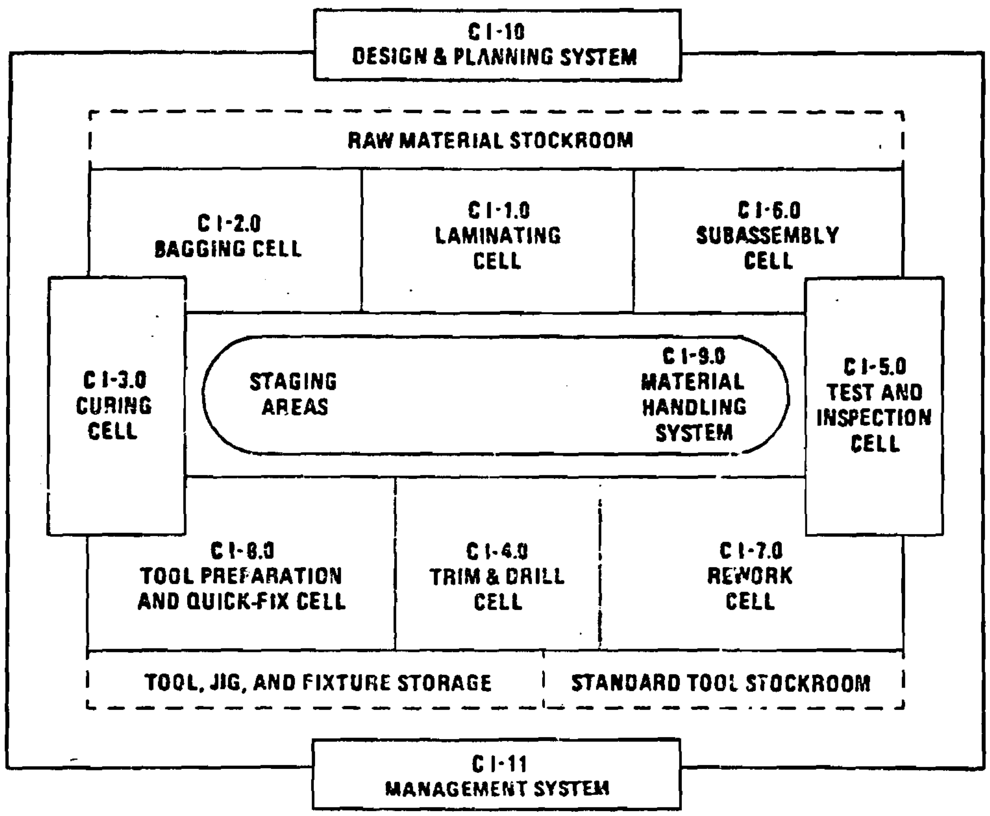


Figure 3-20. Generic Example - ICC Layout (Not to scale)

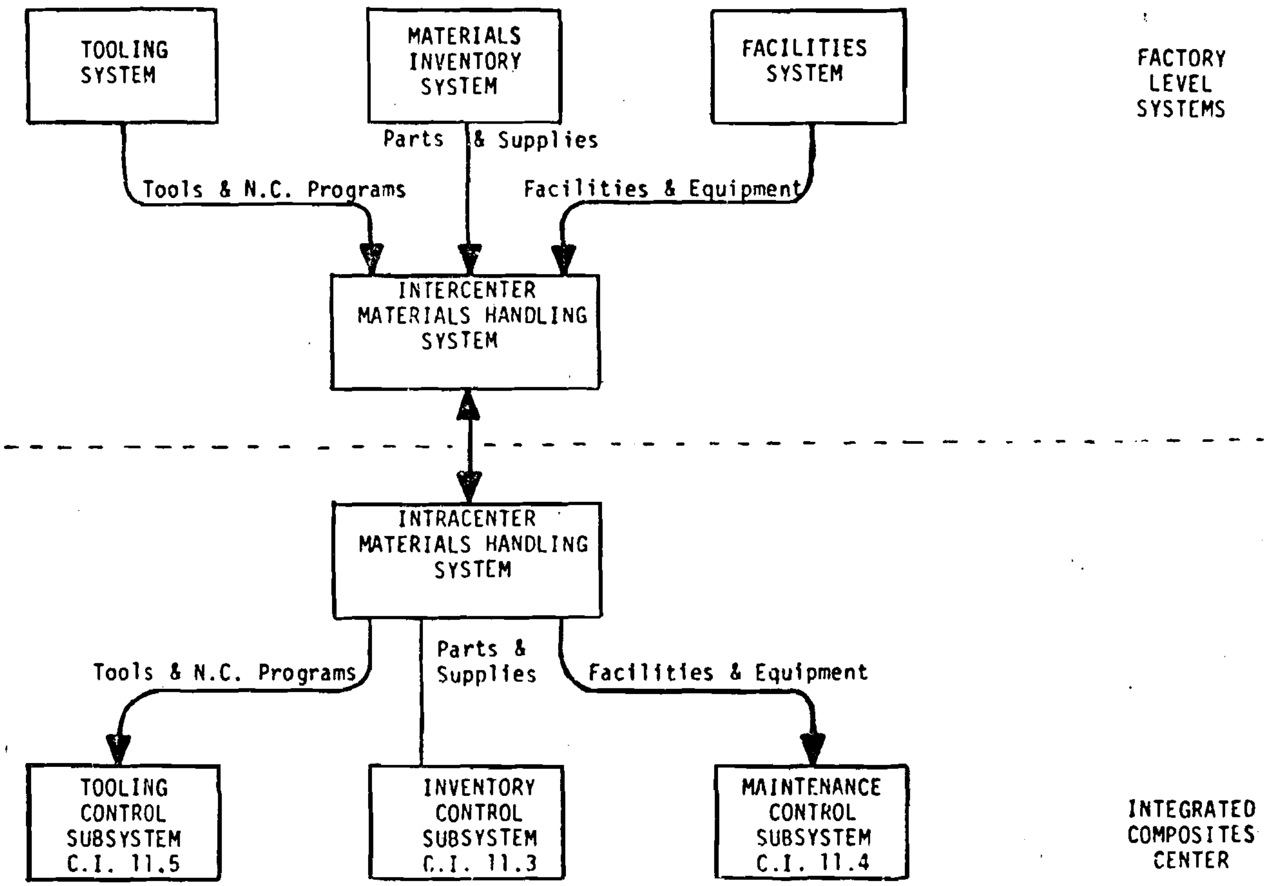


Figure 3-21. Physical Factory/ICC Interfaces

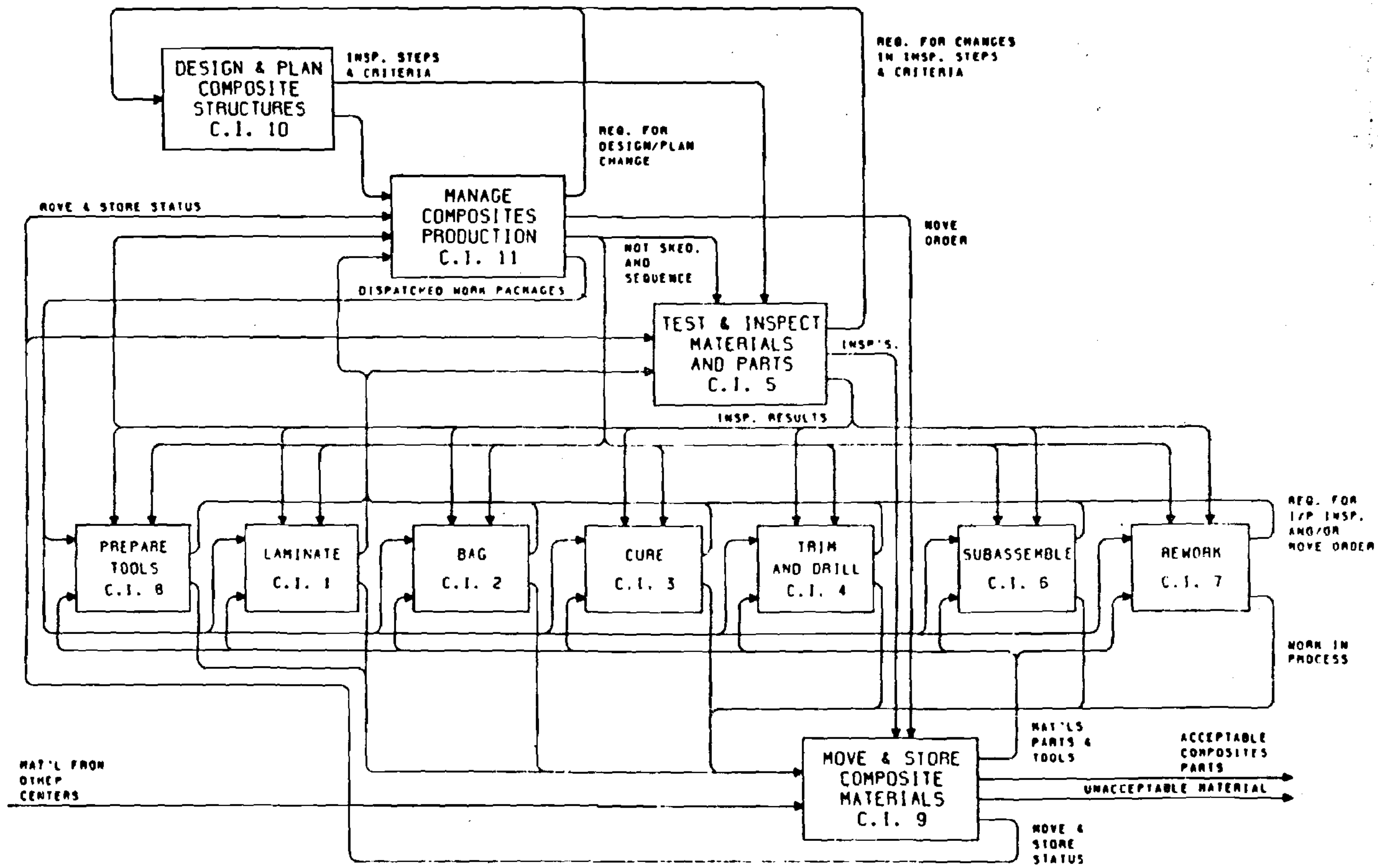


Figure 3-22. IDEF Activity Model of the ICC

each of the fabrication and/or subassembly centers, will be relegated to Factory level systems. This will allow the ICC to specialize within its specific production requirements. To ensure that the ICC does not negatively impact the overall factory operations (and to ensure that the overall factory operation does not negatively impact the ICC), an overall systems framework will be established to describe the necessary degree of integration between the Northrop factory and the ICC. The specific degree of coupling between the systems internal to the ICC (largely oriented to composites manufacturing) and the Factory level systems which support the overall factory operation will be detailed as the ICC system design matures. Because the ICC is seen as a "new" subsystem within a relatively "old" Factory system, it is likely that the ICC design will require performance that the current factory level systems cannot support. In these cases the specific performance requirement will be identified and a means for its satisfaction will be recommended. The specific issue of how the ICC will be implemented within the Northrop environment is the subject of the ICC Implementation Planning Document. This document will be produced as the final product of the Preliminary Design Program.

- <u>Production Parameters</u> - Northrop plans to become a leading producer of aerospace composite structures. To accomplish this goal, Northrop has chosen to include both the production of large and small aircraft components within its production requirements envelope of its ICC. Allowing the ICC to be effective for at least a decade, possibly longer, before major changes are needed. Because of the uncertainties inherent in predicting the future, the ICC design team included flexibility based upon continuous trend analyzing supported by expert opinion as a key design feature. Northrop's ICC system design is based upon the current F-18A and F-20 production requirements as well as possible evolutionary developments which could cause these aircraft to evolve into largely composite airframes. Furthermore, to improve ICC capabilitiy, Northrop included the production of a large transport type aircraft in its ICC requirements envelope.

- <u>ICC Functional Parameters</u> - Northrop's ICC produces airframe composite structures according to engineering designs and specifications, contractual delivery rates and dates, and approved cost targets. Functionally, the "TO BE" ICC is equivalent to the "AS IS" composites center in terms of what it must be capable of doing. The differences between the "AS IS" and the "TO BE" ICC is in how these functions are performed. Through the use of advanced technology and rigorous system development methods, the "TO BE" ICC will be designed to: reduce the cost of producing composite structures; increase their quality; and provide a degree of flexibility impossible to achieve within the current composites center. Increased flexibility (which is often difficult to quantify) will be manifested in an enhanced ability to respond, in a cost effective manner, to changes in production rates, product mix and material systems. One of the key requirements of the ICC is that it be based upon an "open-ended" design. That is, the ICC must be capable of being expanded to satisfy future requirements without causing major obsolescence, high cost, undue risk or production interruption.

- <u>Physical Parameters</u> - The physical requirements of Northrop's ICC will become more detailed as the design progresses through the Preliminary and Detail Design phases. Production rates and volume requirements will be the principal drivers. It is estimated that Northrop's ICC will require approximately 350,000 square feet of floor space. The use of overhead space for vertical racks, hoists and monorails will provide flexibility and allow denser packing of ICC components into the same floor space.

  The current capacity of Northrop Building 905 will support most predicted ICC requirements. A possible exception may be the need for a separate facility to produce very large components for the Large Advanced Subsonic Transport (LAST) aircraft. This, yet to be designed, aircraft may require a 160,000-square-foot facility for the production of an integral wing and/or fuselage. It is unlikely that both structures would be produced at Northrop due to volume, cost and risk constraints. It is assumed that one facility will be needed which can house one or more complete wings and/or fuselages. It is also likely that the layup, cure, trim and inspection of this structure would be carried out in this external facility. The operation of both the ICC (Building 905) and the LAST facility (if needed) would be controlled by the ICC control system. If the LAST facility were geographically distant from the central ICC, a subset or copy of the ICC control system could be used to minimize the telecommunications costs.

  The ICC will include an environmental control system that will allow selected temperature, pressure and humidity ranges to be maintained. In addition, dust and other contaminants must be controlled within the ICC. These environmental controls will be controllable to meet specific processing requirements of the various cells and work stations. In addition, they will satisfy customer and Mil-spec requirements.

- <u>Performance Parameters</u> - The ICC must meet future production requirements, schedules, cost and quality goals. It can not become the "critical path" for producing aircraft nor the constraining element in responding to product or production changes. Consequently, following requirements will be met:

  - Effective and responsive planning and control of production capacity, requirements and status
  - Redundancy, where required, to avoid catastrophic failure of key system components
  - Queues, banks and cushions planned and controlled to ensure a smooth flow of work
  - Avoidance of work flow ddisturbances.

- Interface Parameters - The ICC must be integrated in two major ways: (1) so that each element supports and complements all other system elements, and (2) to be an integral part of an overall factory system. Integration will be accomplished through an integrated control system and through the intercell materials handling system.

  While the ICC is being designed as an integral part of Northrop's Factory operation, it will be considered as a new or "TO BE" system. Unfortunately, Northrop's external (to the ICC) Factory systems are not new. The design of a "TO BE" center in an "AS IS" Factory is most challenging. While it is certain that the Northrop Factory systems will evolve over the ICC development time-frame, the exact nature and rate of this evolutionary process is difficult to ascertain.

  Figure 3-23 shows the relationship between the ICC and the Northrop factory level systems.

- Design Constraints - The ICC is designed to produce Northrop's composite airframe components. Its design, to a large extent, is constrained by the design of the component parts, the materials selected and the inspection requirements as well as the production rates and schedules which are levied upon the composites center. The major design constraint is that the "TO BE" ICC must work in Northrop's real-world environment. The "TO BE" ICC must produce quality products at rate, to schedule, and at a significantly lower cost and risk than the "AS IS" system. It must also be flexible enough to satisfy these requirements for at least 10 years without requiring major revisions.

- Design Strategy - In the design of Northrop's "TO BE" ICC each function required to produce composite structures in the current and projected future environment has been analyzed. For each function, improvement potential was ascertained based upon available and soon-to-be available methods and techniques. Many improvement concepts imply a substitution of mechanized and/or automated processes for current human labor-intensive operations. These substitutions are desirable for three reasons:

  - Mechanized equipment can produce the same level of output as its human counterpart for less cost

  - Mechanized equipment can be controlled more effectively than humans, thereby increasing the "quality" of the productive output

  - It may be difficult to find humans who are willing and able to perform adequately in some production environments.

Each ICC function was been analyzed in light of these three factors. The appropriate degree of mechanization and automation resident in the ICC is worthy of analysis. The final decision has yet to be made because this analysis is still under way. However, certain design groundrules have been established which impacted the System Design Specification. These groundrules are:

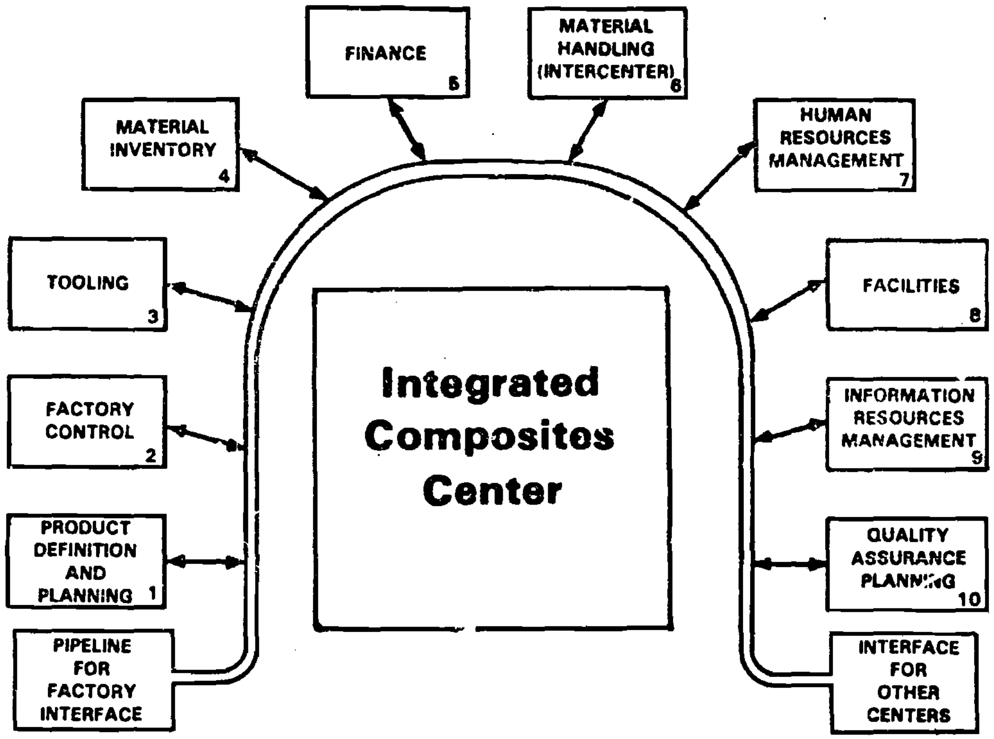


Figure 3-23. ICC Factory Systems Interfaces

- o Mechanization/Automation will be used where the costs and risks clearly indicate large cost savings potential

- o Available equipment, facilities, and tools will be utilized where the cost of replacing them (for the purpose of mechanization/automation) cannot be justified.

- o Flexibility, reliability, maintainability and safety will be primary considerations in the use of mechanized/automated equipment and processes

- o Mechanization/automation will not be used solely to remove humans from composites manufacturing operations except for reasons of health or safety

- o Northrop's will remain "a good place to work" for humans; the ICC will make it "a better place to work."

o Quality Assurance Parameters - Northrop's ICC is being designed to replace the "AS IS" composites production center. The quality requirements of the "AS IS" system will be imposed upon the "TO BE" ICC. This means that the ICC must produce composites structures at quality levels specified by the customer, military specifications and the product design. The success of the ICC will be measured in terms of how well these standards are met. The goal of Northrop's ICC "TO BE" design is to produce acceptable parts every time (no scrap) at a total cost which is lower than the "AS IS" system. Rework cost goals have been set at 5% of direct labor hours. The effectiveness of the ICC design will be determined by how well these goals are met.

o ICC Configuration Items - In the factory hierarchy, the ICC is comprised of cells, stations, positions, processes and operations. To simplify the description of the evolving ICC design, areas which clearly can be identified as physical entities will be considered cells, stations and positions. Less tangible subsystems which deal with information processing or decision-making, which are more logical constructs than physical locations, will continue to be called subsystems.

The distinction between cells and subsystems is made for convenience in understanding the ICC design. The actual delineation between the two is somewhat arbitrary. This System Design Specification is focused upon the ICC itself (as a system) and its component cells and subsystems. Descriptions of stations, modules and equipment will be contained in subsequent documents. Figure 3-24 shows the major components of Northrop's ICC. This schematic diagram shows only major functional elements of the ICC; scale and functional relationships are not shown.

Appendix A of the System Design Specification (SDS110511000) of 28 February 1983 discusses each configuration item independently. Where alternative design concepts are introduced, the benefits and drawbacks of

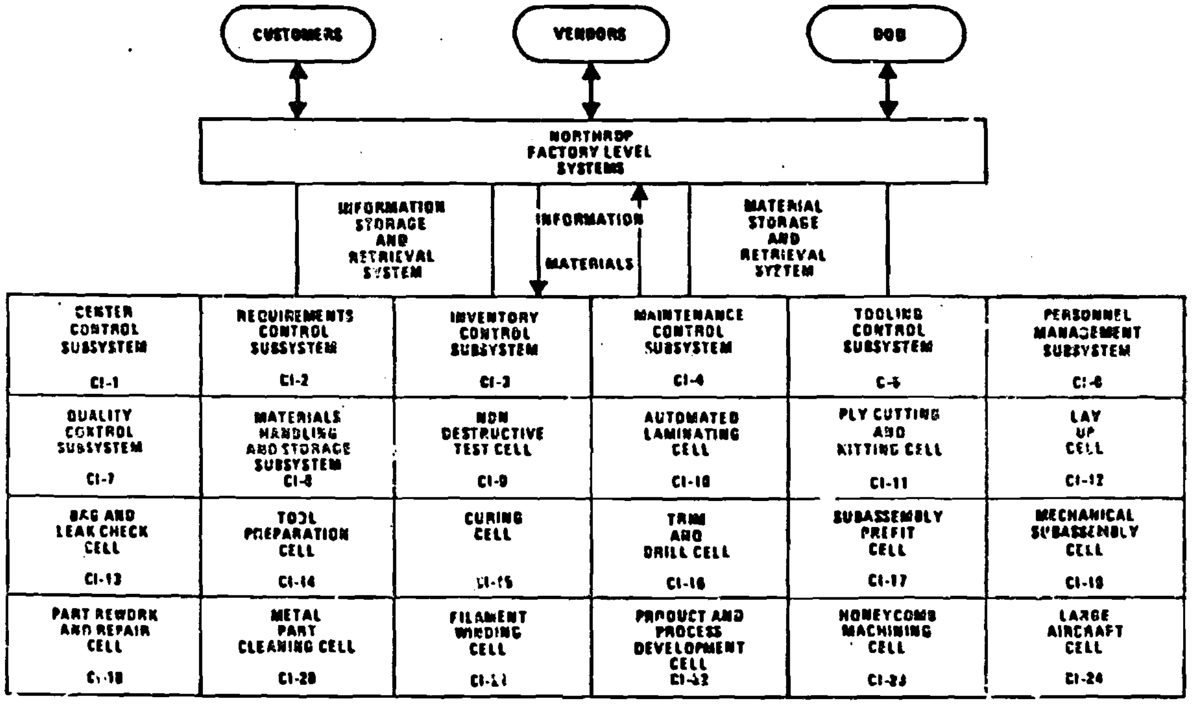


Figure 3-24. Northrop's Integrated Composite Center Configuration Items

each alternative is identified and a selected design, if found to be appropriate, is described.

3.3.8.3.2 Vought's Integrated Composites Center - Vought, as a major aerospace subcontractor, produces a large product mix of fiberglass, Kevlar, graphite and hybrid composite parts at variable production rates. To meet the requirements of its customers, Vought designed a flexible ICC which could fabricate different products at will -- cheaply and in small quantities. The functional areas of the ICC are called cells; the interfaces between these cells are defined as subsystems to the factory level system.

In the future, the control structure will consist of a factory which manages one or more cells which in turn, manage one or more stations. The station may perform one or more operations to accomplish a factory objective. Figure 3-25 is based on the Factory of the Future concept developed by the Task B coalition. It depicts the interaction between centers. Figure 3-26, Produce Composite Structures, depicts the interfacing/interactions between centers at the factory level. Figure 3-27 depicts the interfacing/interactions/integrations between the center/cells within the ICC system in general.

- ICC Cells at Vought - The following cells are involved in the production of composite structures at Vought. A complete definition of their structure and function can be found in Appendix B, System Design Specification (SDS110511000) dated 28 February 1983.

  - Manufacturing Engineering and Control Cells. These provide the technical support and control for the ICC; i.e., cost, scheduling, developing and management reports.

    - Manufacturing Engineering Composite Cells
    - Manufacturing Control Composite Cells

  - Production Control Composite Cells. These provide for the storage of materials and details, kitting of work packages, movement and tracking of work packages between cells and the storing and tracking of tools.

    - Manufacturing Requirements and Order Release Control Composite Cell

    - Production Control Composite Storage/Kitting Cell
      Shop order file
      Refrigerated material storage area
      Cut ply kit storage/tracking
      Inventory computer terminals

    - Production Control Moving/Tracking Cell
      Work package and material moving
      Automated guided vehicles
      Tool storage and management

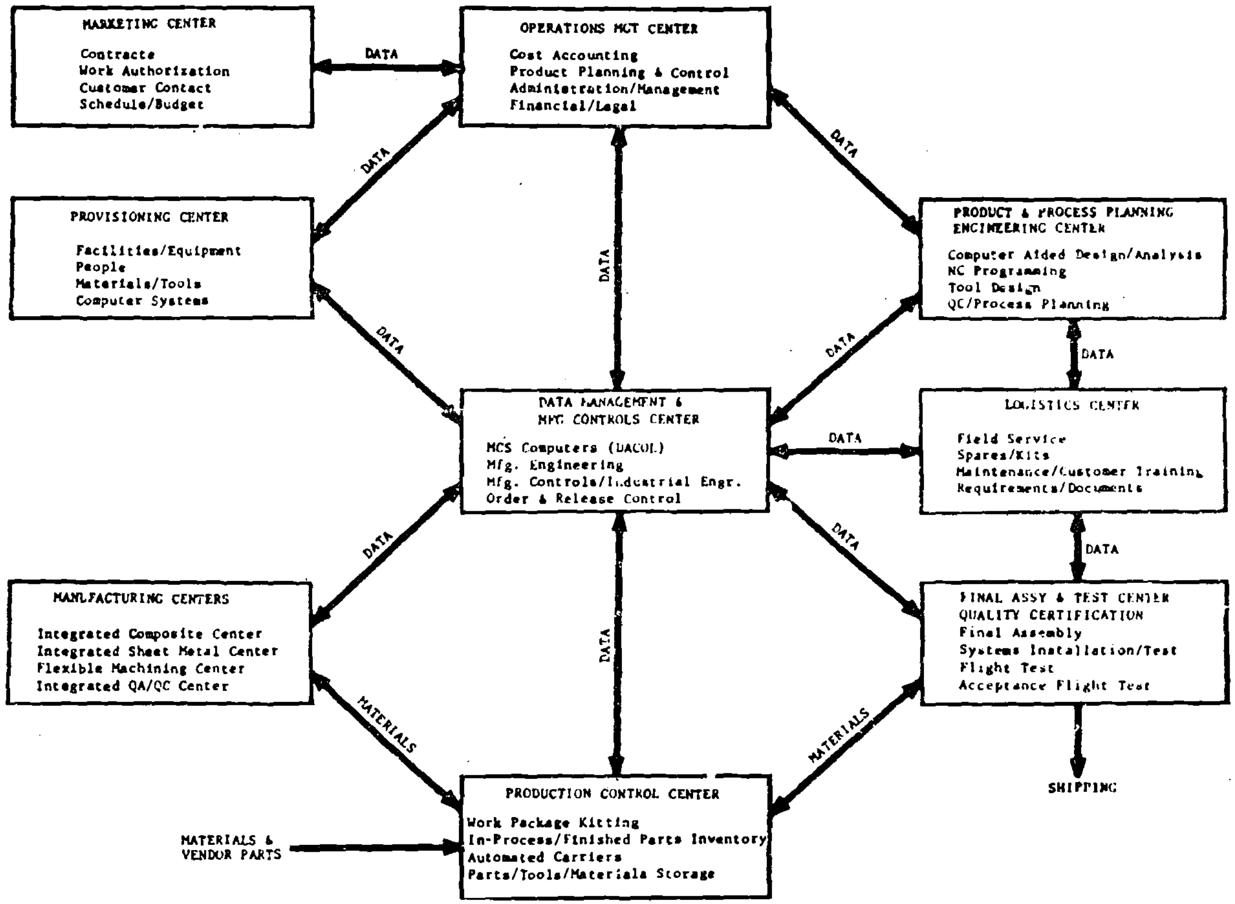


Figure 3-25. Factory Level Concept

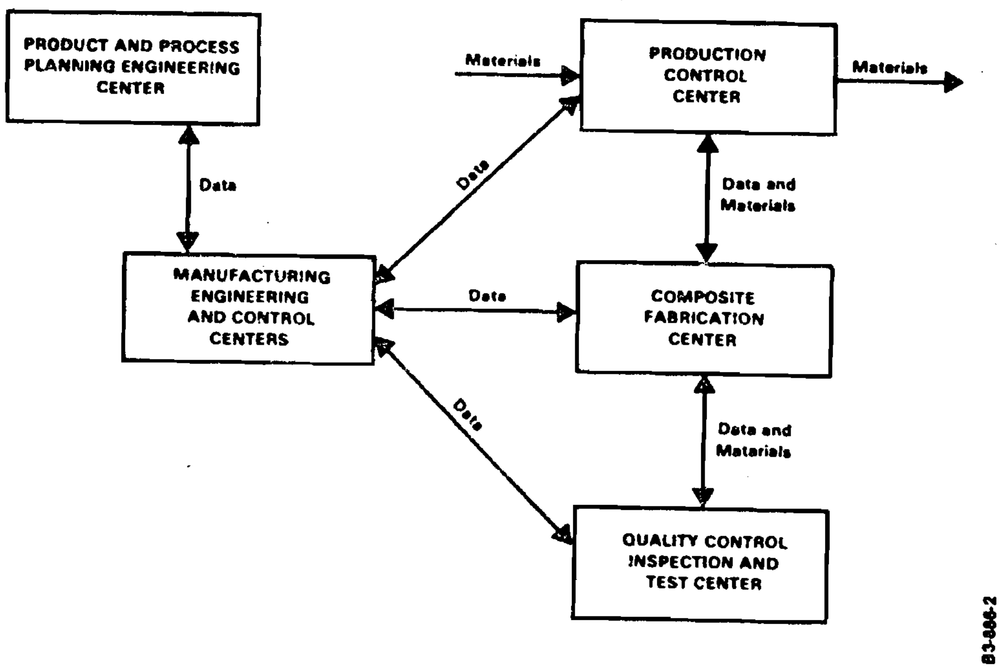


Figure 3-26. Produce Composite Structures

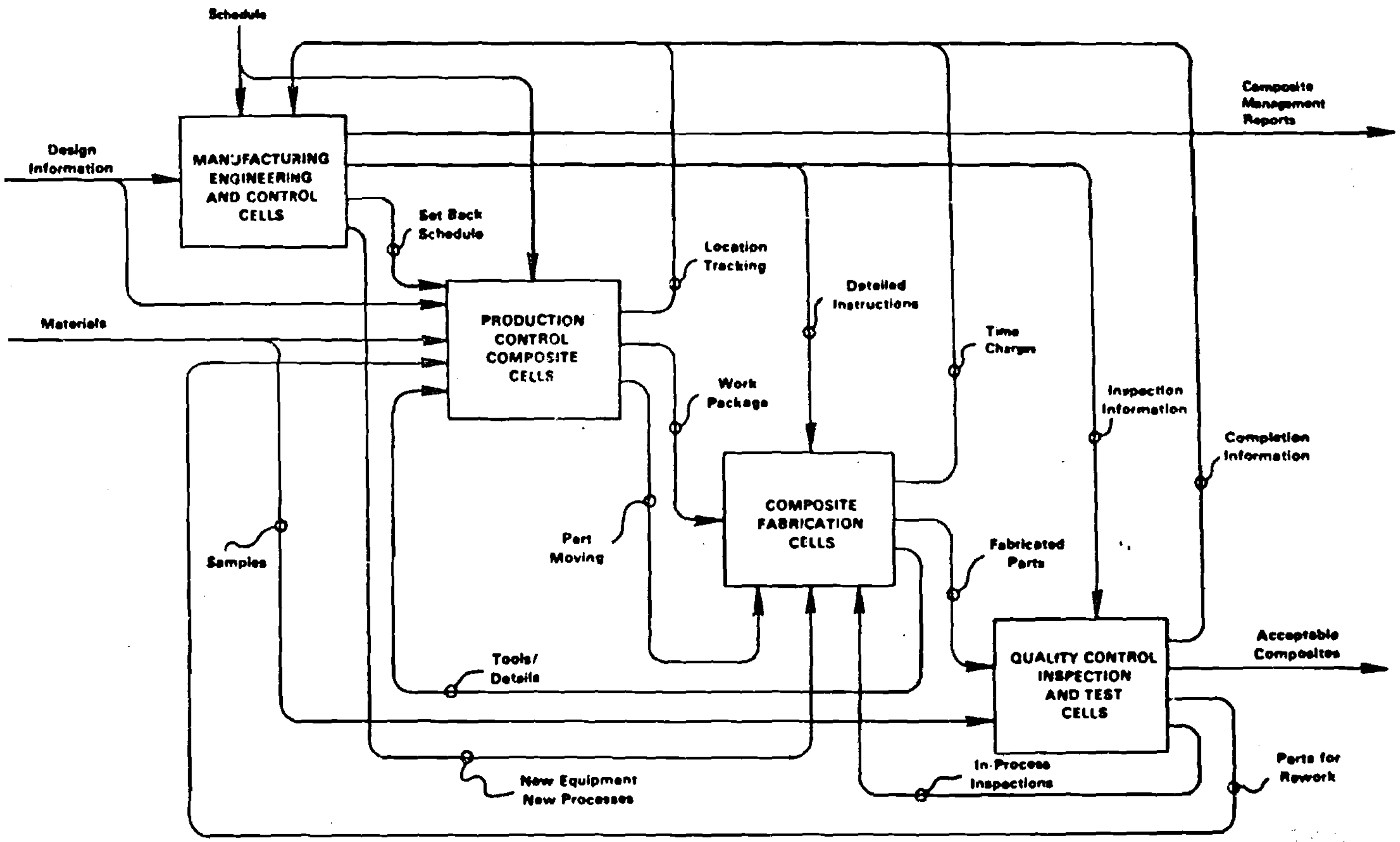


Figure 3-27. Integrated Composite Center Function Interface

- Composite Fabrication Cells. These receive work packages from production control, fabricate the required parts/details with the aid of detailed instructions and forward the completed items to Inspection. This is a semiautomated, mechanized system. These cells are charged with core fabrication, shaping, forming, potting and curing. Other cells within the Composite Fabrication Cells are:

  o Ply cutting cell
    Composite material preparation
    Automated tape laying machine
    Woven fabric laminating stand
    Rapid ply cutter
    Material handling equipment

  o Layup and Assembly Cells
    Laminating
    Pick and place robots
    Overhead broadgoods dispenser
    Computer terminals
    Local storage oven
    Complex parts forming area

o Manual Laminating Cell

o Filament Winding Cell

o Vacuum Bagging Cell

o Thermal Cycling Cell
   Autoclave staging area
   Autoclave
   Post-curing ovens

  o Tool Preparation Cell
    Tool teardown and preparation area

  o Trim and Drill Cell
    Automated equipment (robotics)
    Hand controlled waterjet cutters

  o Composite Rework/Repair Cell

- Quality Control Inspection and Test Cells. Provides inspection for incoming material, in-process inspection services for fabrication control, non-destructive testing of cured composite components and final inspection.

  o QA Material Evaluation and Destructive Test Cell
    Cured laminate test
    Uncured material test
    Chemical characterization

- o QC Non-Destructive Investigation Cell
  Radiography
  Ultrasonic
  Manual tapping

- o In-Process and Final Inspection
  Shop floor inspections
  Automated equipment monitors
  Three-dimensional inspection equipment
  Computer-aided records
  Material Review Board

o <u>Subsystem Identification</u> - Within the Vought ICC, the functional interfaces between centers are identified as systems and given unique Configuration Item numbers. Subsystems are given lower level numbers corresponding to its upper level system. Figure 3-28, Integrated Composite Center Control Systems, shows the factory level systems interface with the ICC. This interface provides the design strategy to be followed when identifying the various configuration items.

- <u>Design/Manufacturing Interface System</u>. Must be defined early enough in the production life cycle to ensure a parts definition data base that can be readily utilized by manufacturing. Group Technology, Generative Process Planning and 3-D Solid Geometric Modeling will all be major factors in the successful development of this data base. Some of the design/manufacturing interface subsystems are:

  - o Parts Definition Data Base
    Computer-aided design
    Group Technology
    Generative Process Planning

- <u>Manufacturing Control System</u>. This system provides the control and tracking of the shop orders written and released by the Manufacturing Requirements and Order Control Cell. The Manufacturing Control System provides a hierarchical control based on the center-cell-station-operation organization structure. It allows flexibility and growth in the control hierarchy of each individual center. Some of its subsystems and parts are:

  - o Composite Center Control
    Composite Data Collection (DACOL)
    MCS Master File
    DACOL Card Readers
    MCS Computer Terminals

  - o Composite Management Reports
    Daily Report Computer Programs
    Weekly Report Computer Programs
    Special Report Computer Programs

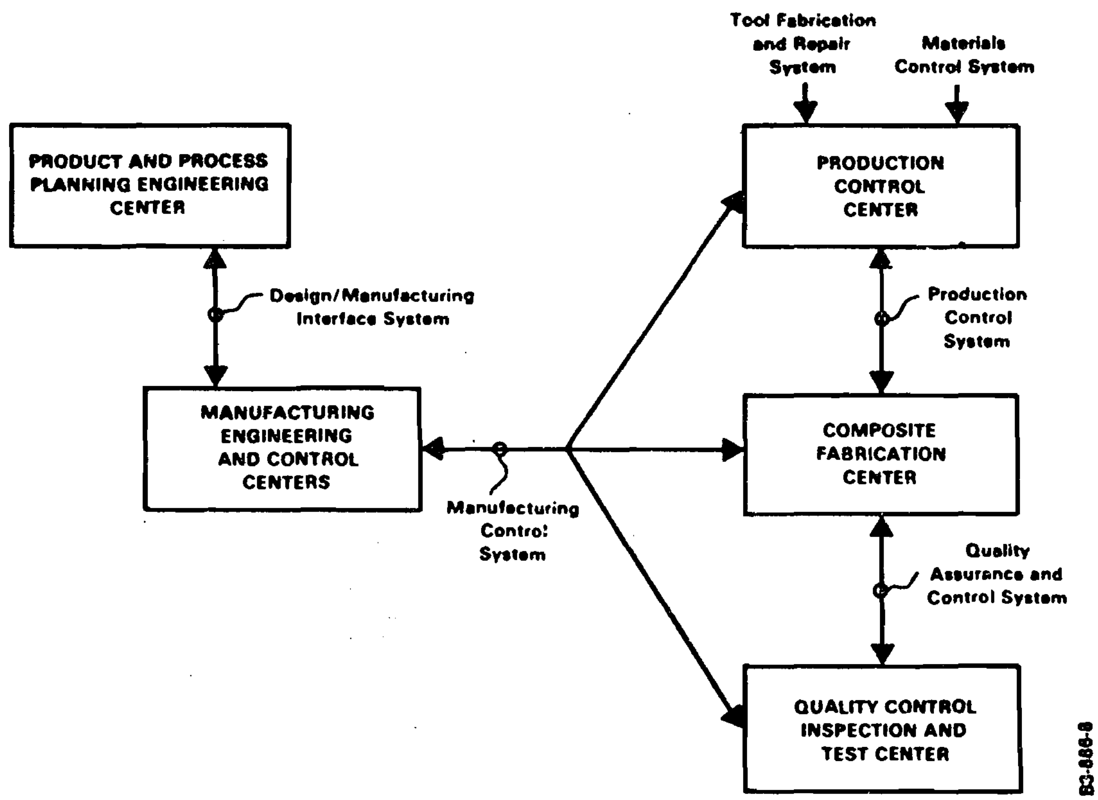


Figure 3-28. Integrated Composite Center Control Systems

- o Information Storage and Retrieval
  Material Control Interface
  Tool Fabrication and Repair Interface
  Quality Control Interface
  Storage Control Interface
  Product Design/Producibility Analysis

- o Composite Facilities Management
  Maintenance Control
  Work around Plan Development

- o Composite Personnel Management
  Operator Identifications and Information
  Shop Loading

- o Integrated Management
  Automated and semi-automated support systems
  Coordination and control of overall ICC requirements

- Production Control System. This system determines the ICC manufacturing requirements, controls the work-in-process to satisfy those requirements, provides the detailed instructions for the work-in-process, stocks and controls the materials required for processing, and provides the tool storage/tracking for component fabrication. Some of its subsystems are:

  - o Manufacturing requirements
    Part requirement and completion file
    Computerized master schedule

  - o Order and Release Control
    Automated order writing
    Detailed instructions
    MOD/change records

  - o Storage/Kitting Management
    Automated parts storage and retrieval
    Automated material storage and retrieval
    Automated cut ply kit storage and retrieval
    Perishable material out-time tracking
    Material usage
    Automated part moving
    Schedule priority change

  - o Tool Storage/Tracking
    Automated tool location/status
    Automated tool storage and retrieval
    Interface with tool fabrication and repair system

- Material Control System. This system provides inventory management and control for all materials used in the ICC. It provides a way to forecast and control inventory requirements and computerized tracking of perishable material out-time and detail parts storage and inventory. The major components of this system are:

  o Composite Material Control
    Automated Material Forecasting
    Material Inventory and Usage

  o Perishable Material Tracking and Control
    Bar code readers
    Material out-time tracking

- Tool Fabrication and Repair System. This system Provides the tracking and control of new tools being fabricated and tools being repaired/updated to be used in the ICC. The system interfaces with CAD/CAM to produce replicates derived from mathematical models when designing and fabricating new tools. Its subsystem and parts are:

  o Composite Tool Management
    New tool status
    Tool repair/update status

- Quality Assurance and Control System. This system provides controls, quality requirements and instructions and collects information for materials and processes used in the ICC. The system will interface with materials control, in-process inspection and automated equipment monitors, inspection and test results, and the MRB. The system will provide accept/reject criteria, statistical analyses, link with computer-aided design and maintain documentation. Some of its subsystems are:

  o Composite Material Control
    Computerized control tags

  o Inspection and Test Data Collection
    In-process inspection
    NDI results and records
    MRB results and records

  o Final Inspection Data Collection
    Final Inspection Data

3.3.8.3.3 General Dynamics Integrated Composites Center

General Dynamics strategy in structuring its "TO BE" Integrated Composites Center was to design it for the 1990-1995 time-frame with capabilities within the realm of the mid-1980's technologies. By incorporating the enabling technologies from its past development programs and aggressively filling identified technological voids, they developed an implementable system with enhanced manufacturing capabilities. These capabilities with "designed-in" flexibility will enable General Dynamics to produce cost-effective, high-quality weapons systems with composite components well into the next century.

The following paragraphs summarize the functional characteristics, operating environment and design specifications for production equipment and support systems envisioned in an ICC at General Dynamics' Fort Worth plant. For a more detailed description of this ICC, refer to Appendix C, System Design Specification (SDS110511000) dated 28 February 1983.

A functional description and design specification for the three support systems and seven major cells found in the ICC follows.

- Support Systems - The three support systems common to all cells within the ICC are the:

  - Automated Material Handling System (AMHS)
  - Automated Quality Assurance System (AQA)
  - Identification and Code Recognition System (ICRS)

  These systems will be integrated through the ICC central computer to provide the necessary part transportation, traceability and quality assurance for a totally integrated center.

  AMHS is a computer-controlled transportation system responsible for moving and queuing materials, parts and tools throughout the center. While there are various automated material handling systems available today, some design modifications will be required to increase their flexibility and capabilities. These modifications will include such features as improved positioning capabilities and improved load/unload capabilities. Major components of this system are:

  - AMHS computer
  - AMHS transportation carts
  - AMHS overhead transport

  The AQA System retrieves, analyzes and stores quality data. Terminal sensing devices at specific locations will receive/transmit data to the system computer. Developments in sensor technology will be a key element in the AQA system. A means for retrieving real-time quality data is required for in-process quality control. Figure 3-29 illustrates the functions performed within the ICC and the processing data required to support a quality data base. Major components for the AQA System are:

  - AQA computer
  - Peripheral devices
    Data terminals and CRTs

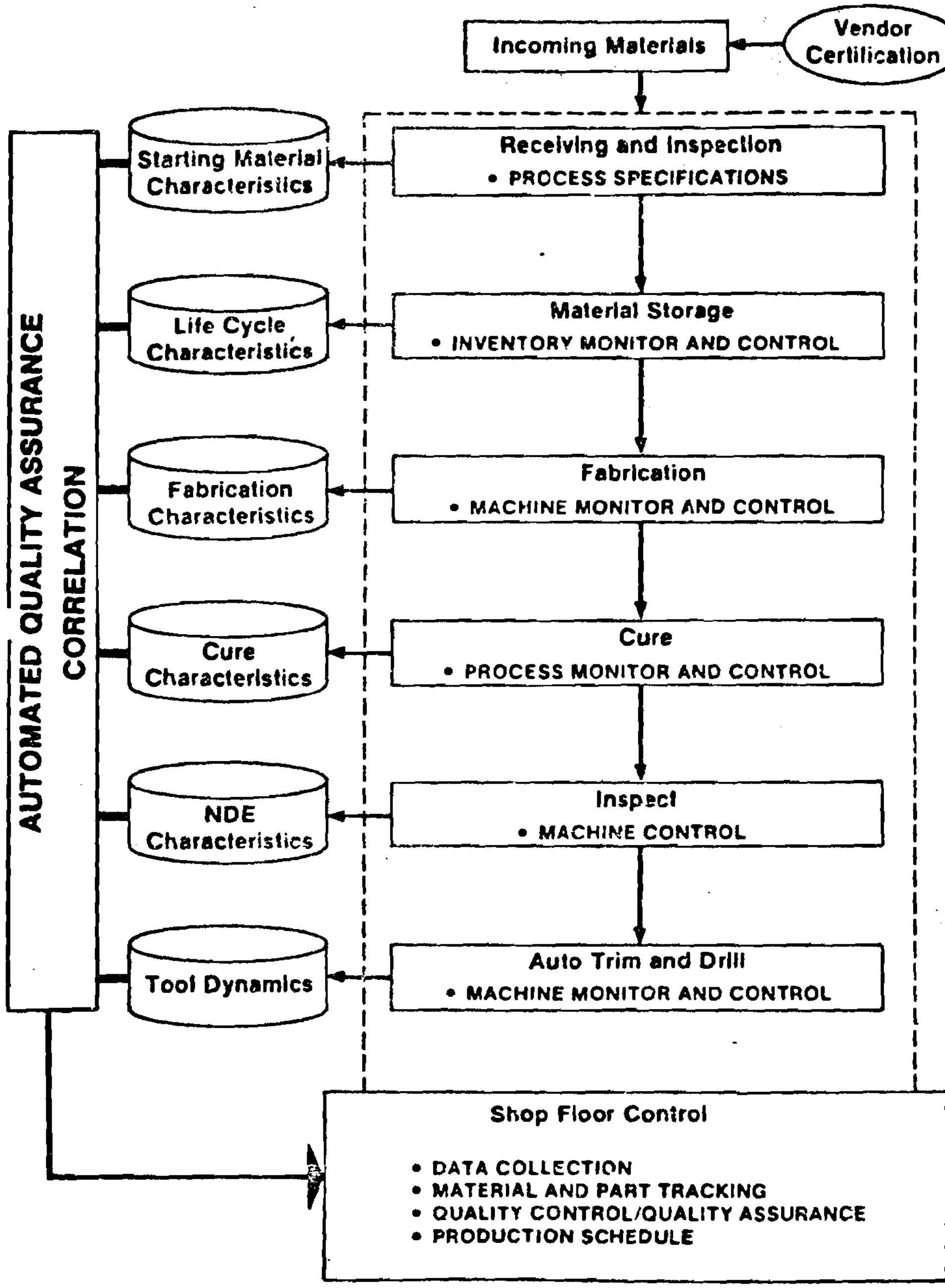


Figure 3-29. GD/FW ICC

The ICRS codes and identifies materials, parts and tools as they enter the ICC and move through the functional cells or specialized work stations. The system will provide the material/part/tool traceability necessary for the center. Code labelers and readers will be distributed throughout the center.

A bar-type coding system is envisioned for the center. A present area of concern in this method is the labeling material with which the bar code is printed. It must not be deleterious to composite materials and must be able to withstand the various processes associated with composites manufacturing. Two major components for the ICRS are:

- o ICRS computer
- o Labeler/reader
  Bar code

o Major Cells - Major cells within the ICC are:

- o Receiving and storage
- o Plastics fabrication
- o Composite laminate fabrication/component build-up
- o Cure process
- o Tool prep and storage
- o Inspection
- o Part drill and rout

Figure 3-30 illustrates the ICC's hierarchical control structure and lists specific equipment required for each cell.

The Receiving and Storage cell provides for the automated storage and retrieval of materials and parts within the composites center. Components of the cell are:

- o Automated storage and retrieval system (AS/RS)
  - Refrigerated
  - Non-refrigerated

- o Receiving inspection
  - Manual code labeling and reading device
  - Data terminal
  - Pre-preg analysis
  - Adhesive, resin, sealant analysis
  - Mechanical destructive test apparatus

Plastics Fabrication processes include Resin Transfer Molding (RTM) and High Performance Thermoplastic Processing (HPTP). Components of this cell are:

- o RTM
  - Resin transfer molding machine
  - Oven (batch-type)
  - Stretch former
  - Broadgoods spreader

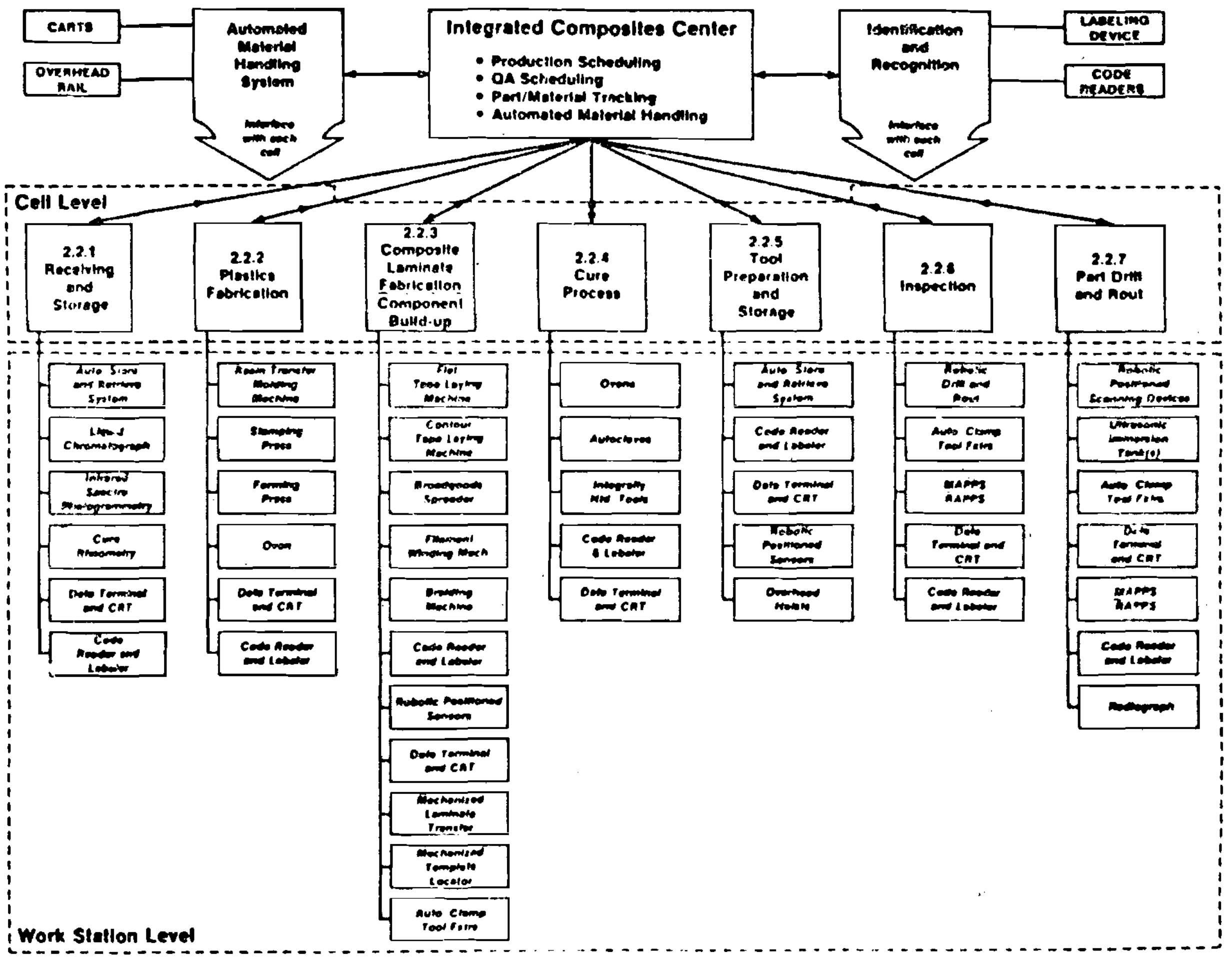


Figure 3-30. ICC Hierarchical Control Structure

- o HPTP
  - Oven (continuous feed)
  - Waterjet cutter

  - Stamping press
  - Inductive heating roll
  - Thermoplastic pultrusion machine

- o Peripheral devices
  - Code reader and labeler
  - Data terminal and CRT

The Composite Laminate Fabrication/Component Build-up cells provide automated placement of materials, the build-up of various laminated structures and components and the bagging of these structures for curing. Equipment in this cell will provide the capability for placing multiple composite materials onto flat, concave/convex, cylindrically and elliptically-shaped structures. Some components of this cell are:

- o Tape laying machines
  - Flat layup surface
  - Contour layup surface

- o Broadgoods spreader/cutter
  - Automated material dispense, steel rule die/hydraulic press
  - Filament winding
  - Braiding machine
  - Spar/stiffener fabricator
  - Component build-up
    - o Wing
    - o Empennage (vertical stabilizer)
    - o Fuselage
    - o Air inlet duct

The Cure Process is performed on thermoset materials. Its function is the automated monitoring, controlling and recording of the critical materials and process variables. Equipment needed for this cell includes:

- o Autoclaves
  - Combustion heat, internal air circulation, controlled cooling
- o Ovens
  - Batch, combustion heat, double-entry
  - Continuous feed, infrared heat, double-entry

The Tool Preparation and Storage cell is designed for the removal of parts from tools, preparation of tools for the next manufacturing sequence and the storage of tools until needed. Tool preparation involves manual cleaning tasks and automated verification systems. Part removal will be a mechanically-aided manual operation. Components of this cell are:

- Tool Storage and Retrieval
    - Automated storage and retrieval system
    - Code recognition capabilities

- Tool Preparation
    - Robotic positioning of sensors
    - Robots similar to the Cincinnati Milacron T^3 model
    - Code recognition
    - Automated tool positioning

- Tool/Part Separation
    - Overhead hoist
    - Code recognition
    - Data terminal
    - Auto tool tab drill

<u>Inspection</u> verifies component and structural integrity, dimensional accuracy, the location of structural members within the component and ascertains the quality of adhesive bonds and seals. Components of the inspection cell are:

- Peripheral Devices
    - Code readers
    - Data terminals
    - Plotters

- Tool Fixtures
    - Adjustable (auto clamp capabilities)
    - Interchangeable
    - Overhead hoists

- NDE
    - Ultrasonics pulse-echo and through transmission
        - Robotic positioned sensors
        - Multi-axis part positioners
    - X-Radiography
        - Digital image processing
        - Multiple energy techniques
        - Stereo fluorscopy
        - Robotic positioned scanner

<u>Part Drill and Rout</u>. Prepares parts and components for installation and assembly. Developing of end effectors equipped with sensors capable of monitoring tool dynamics will eliminate hole and edge delaminations. Real-time monitoring will also diminish the requirements for a post-drill and rout inspection. Components of this cell are:

- Peripheral Devices
    - Code readers
    - Data terminals

- o Tool Fixture
  - Adjustable/interchangeable
  - Overhead hoist
  - Multi-axis part positioner

- o Robots
  - Hydraulic/DC Drive
    - Computer controlled
    - Cincinnati Milacron Type T^3
    - Adaptive control

o <u>System Integration</u> - System integration for the composites center will eventually result from the effective coordination of the technologies being developed under the Air Force's ICAM programs. Through these technologies, there will evolve an ICC that incorporates planning, control and decision support systems with the management of fabrication, quality assurance and material handling/storage processes related to composites manufacturing.

Figure 3-31 portrays a typical environment which will exist at General Dynamics in the 1990-1995 time-frame. This system is currently in the planning stage.

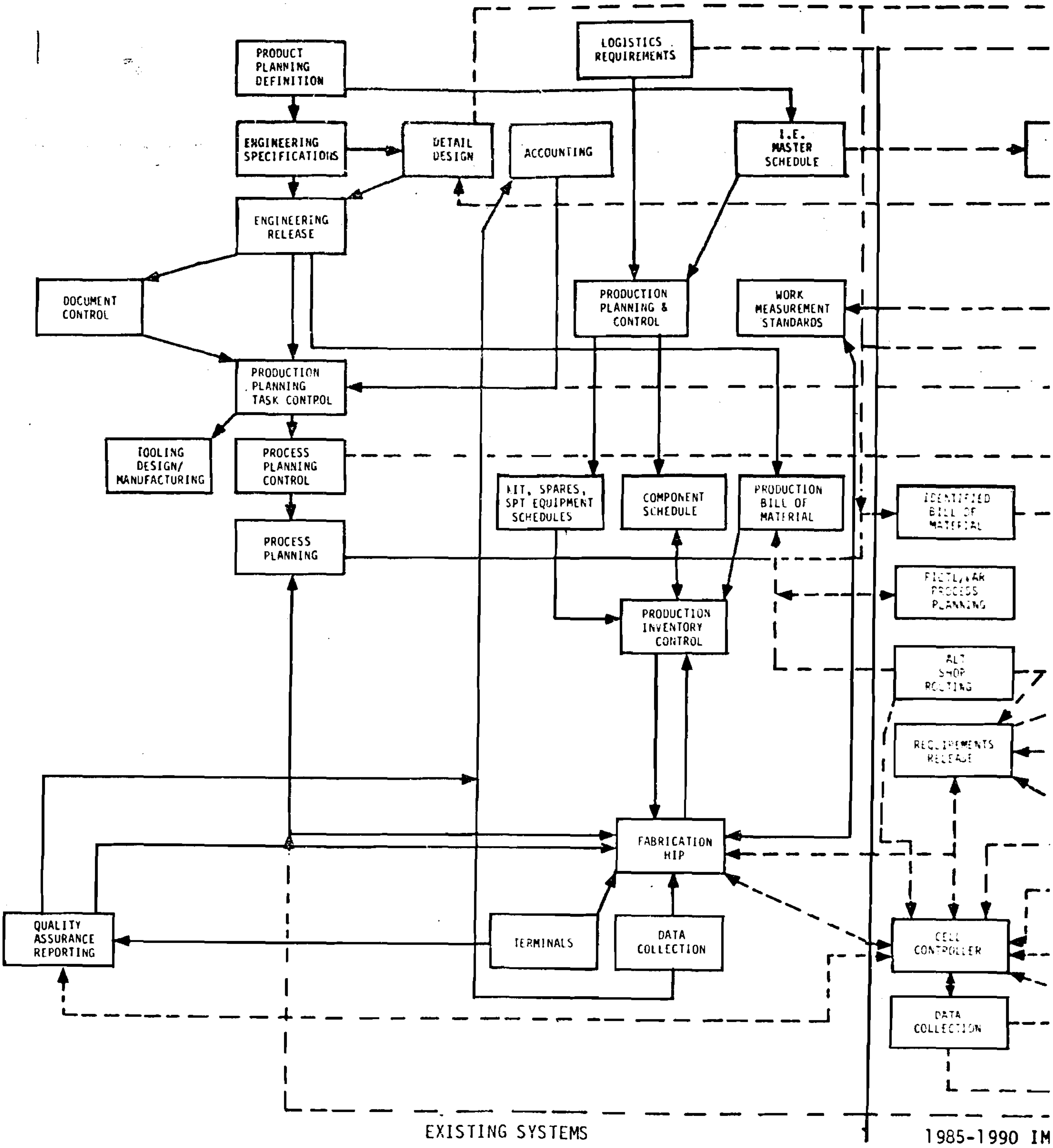
o <u>Product Data Base</u> - At present, there is a need for a product data base for nonmetallic part design and manufacture. With the development of this data base, there will be automatic generation of:

- Composite designs with incorporated manufacturing restraints
- NC/DNC/CNC programs
- Robotics programs
- Automated process planning
- Automated time standards

o <u>Computer-Based Information System</u> - A computer-based information system (CBIS), similar to the one in ICAM 2201, will establish the information network for ICC. It is currently envisioned that there will be four tiers of information within the CBIS.

- Tier One - central processor at Data Systems Division Central Center
- Tier Two - work center controller (ICC)
- Tier Three - work cell controller (composite laminate fabrication)
- Tier Four - station controller (tape laying machine)

Each tier will contain those applications and data bases needed to control functions at its level. Additionally, within Tiers Three and Four, a local area network (LAN) concept will be used where each node, consisting of a mini- or micro-computer, within a tier will function independently of each other.



COMPUTER BASED INFORMATION SYSTEM

Figure 3-31. Systems Su

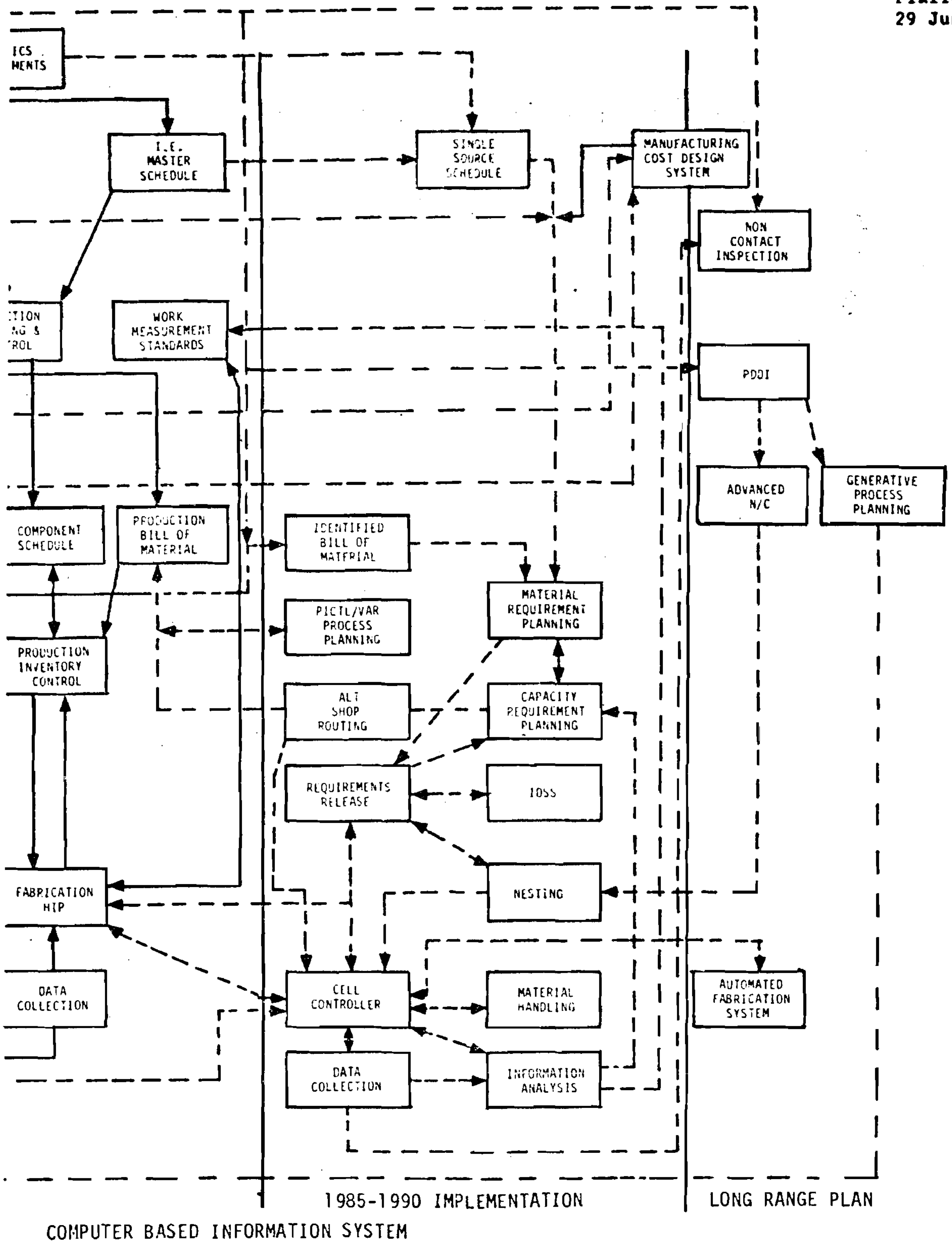


Figure 3-31. Systems Supporting the Integrated Composites Center

- o <u>Tier One - DSDCC</u>. At this highest level, the central processor will coordinate plant wide applications such as: master schedule, inventory control, cost accounting, CAD/CAM, process planning and the Management Information System.

- o <u>Tier Two - Work Center</u>. At the Tier Two level, centralized computer within the center will coordinate such work center applications as: production scheduling, automated material handling, QA scheduling and part identification.

- o <u>Tier Three - Work Cell</u>. The primary function of Tier Three is shop floor control. A Local Area Network (LAN) consisting of a network of mimi- and micro-computers with the following nodes: receiving and storage, plastics fabrication, composite laminate, cure process, part drill and rout, and inspection will assign the work scheduled in Tier Two to the correct machine and employee.

- o <u>Tier Four - Station</u>. This tier consists of the machine controller and operator stations. The process controller passes information regarding the parts to be manufactured. Information is monitored and collected automatically on a real-time basis.

o <u>System Software</u> - The heart of this network configuration will be a data dictionary and data base management system. The dictionary will help define the points of interface and data requirements. The data base management system will coordinate the backend processor. It will require a data base server to:

- Coordinate concurrent access to a given file from multiple requestors
- File sorting
- Catalog management
- Archiving
- Index searching

Improved procedures are needed to effectively translate system requirements into software designs while integrating them with other tasks.

Other systems necessary to implement the Integrated Composite Center are:

- Detail Process Planning Subsystem
- Scheduling and Budgeting System
- Production Planning Control System
- Material Requirements Planning System
- Capacity Requirements Planning System

- Requirement Release System
- Data Collection System

- Information Analysis System
- Inspection System
- Nonconforming Materials System

o Human Factors - User training on the system will be provided as required by job classification. Direct users will interface the system for the purpose of entering and receiving data. Indirect users will require information for planning, forecasting, measuring performance, tracking and cost analysis.

3.3.8.3.4 General Electric's Integrated Composite Center

At General Electric, the integration of composite production with the fabrication and final assembly centers is the responsibility of the factory level control centers function. Figure 3-32, Control Centers Environment, illustrates how the control centers would evaluate a situation and make the necessary schedule adjustments on a problem requiring a change of schedule. The control center function is in a position to place the correct priority on different aspects of the problem as to its relationship with other problems which might coexist.

This control center has the capability to determine fabrication requirements to support schedule changes and to determine any metal parts required and to schedule these requirements from the machining center.

Figure 3-33, Planned Composite Production, shows the planning of orders for assemblies and detail parts to be produced in the composite stations. The planning activity is performed at the center level.

A complete definition of General Electric's Plan Composite Production, (Control Composites Planning and Production Control Composite Stations) may be found in Appendix D, System Design Specification (SDS110511000) dated 28 February 1983.

3.3.8.4 Produce "TO-BE" Integrated Composite Center System (WBS 4.3.8.4)

In response to Task E, WBS 4.3.8.4 Produce "TO BE" Integrated Composite Center, the models and analytical results of the ICC Preliminary Design effort were compiled and documented in the "TO BE" ICC System Design Specification. The quantified benefit parameters of the "TO BE" design were included in this document as well as how the definition of this design satisfied the identified system requirements. The System Design Specification document also included three site specific designs as well as the design of a generic ICC. This WBS item was published as report number SDS110511000, entitled System Design Specification on 28 February 1983.

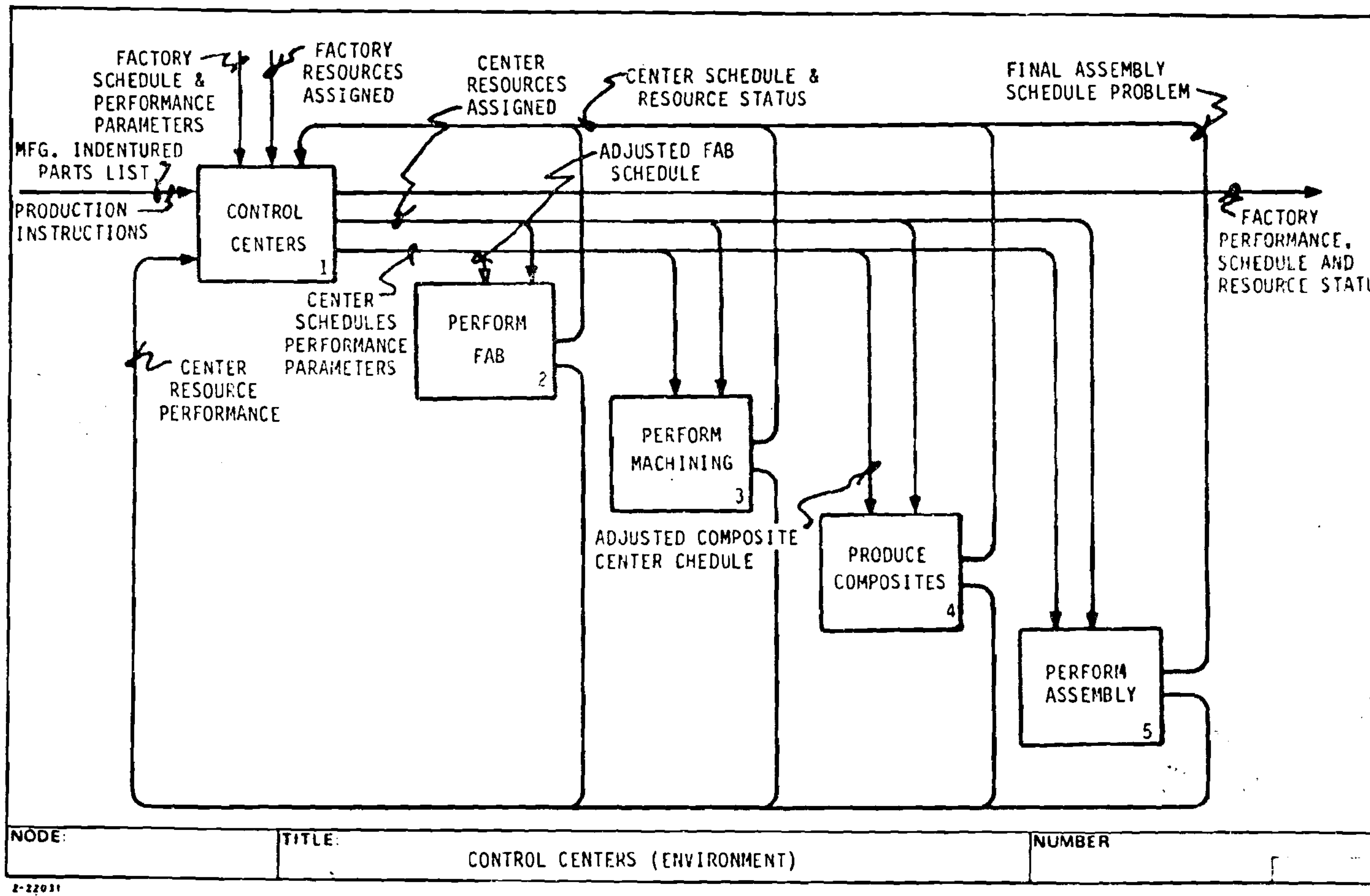
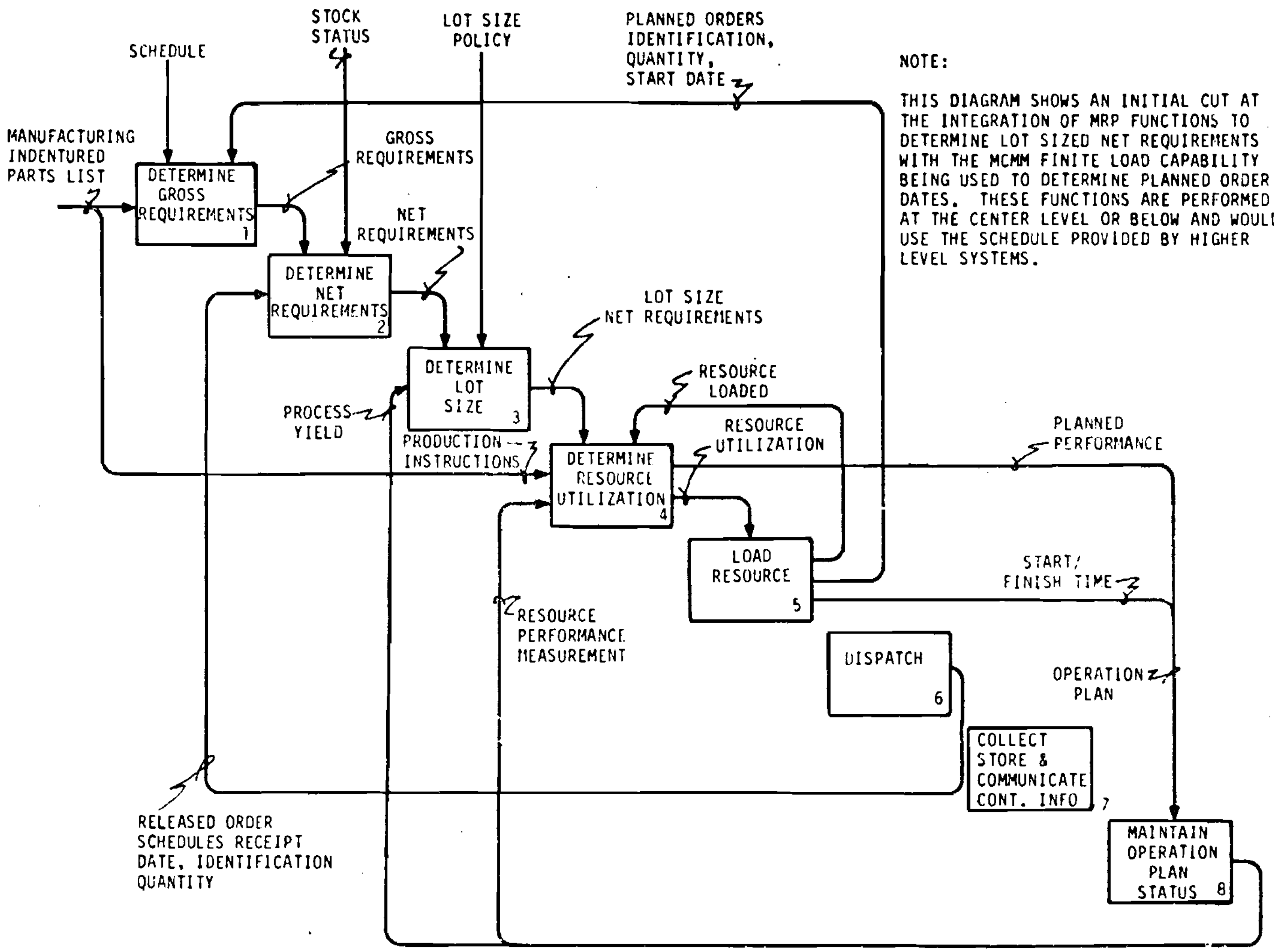


Figure 3-32. Control Centers (Environment)



NOTE:

THIS DIAGRAM SHOWS AN INITIAL CUT AT THE INTEGRATION OF MRP FUNCTIONS TO DETERMINE LOT SIZED NET REQUIREMENTS WITH THE MCMM FINITE LOAD CAPABILITY BEING USED TO DETERMINE PLANNED ORDER DATES. THESE FUNCTIONS ARE PERFORMED AT THE CENTER LEVEL OR BELOW AND WOULD USE THE SCHEDULE PROVIDED BY HIGHER LEVEL SYSTEMS.

Figure 3-33. Plan Composite Production

3.3.8.5 Conceptualize and Document Integrated Composite Center System Configuration (WBS 4.3.8.5)

This document contains the conceptualized implementation strategy for the Integrated Composites Center. It describes the concepts, criteria, standards, tools and strategies for implementing the system and details specific steps necessary to implement this composites technology into new or existing production facilities. This document includes implementation plans for a generic ICC as well as for the specific sites of Northrop, Vought and General Dynamics.

The Implementation Strategy Plan addresses all of the implementation activities and specific steps required for a generic Integrated Composites Center to emerge from a "green field." It discusses each of the Configuration Items that impact the "TO BE" ICC. These Configuration Items are:

- o Composite laminating cell
- o Composite bagging cell
- o Composite curing cell
- o Composite trim and drill cell
- o Composite test and inspection cell
- o Composite subassembly cell
- o Composite rework cell
- o Tool preparation and quick-fix cell
- o Material handling system
- o Design/develop composite structures
- o Composites management system.

Figure 3-34 is a block diagram of the major cells/system which must be implemented for the generic ICC. Figure 3-35 is a block diagram illustrating the implementation items for the laminating cell. Once the generic ICC system design specification has been developed and approved, tasks to convert it into an operating functional organization can be performed on both the cells and systems.

The Implementation Plan Strategy provides a generalized framework of tasks stated in terms of generic cells/system, configurated items and job titles. It includes the various steps that convert a system design into an operaetional system. A general outline of the Implementation Plan Concepts is shown in Figure 3-36.

The Implementation Plan will document the following items:

- o What specification items and task are to be undertaken
- o In what sequence (timeframe) will which tasks occur
- o What specific cell/system is responsible for performing the implementation task
- o What type of system testing is required
- o How will manager/non-manager training be conducted?

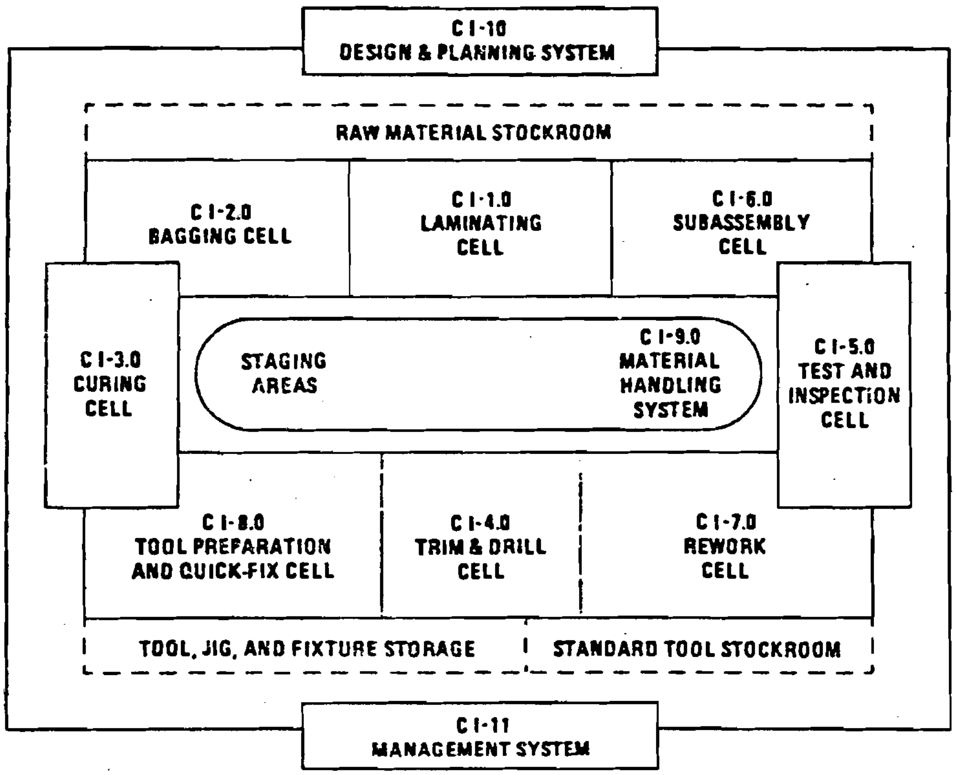


Figure 3-34 Block Diagram of the Cells/Systems that are to be Implemented in the Generic Integrated Composites Center

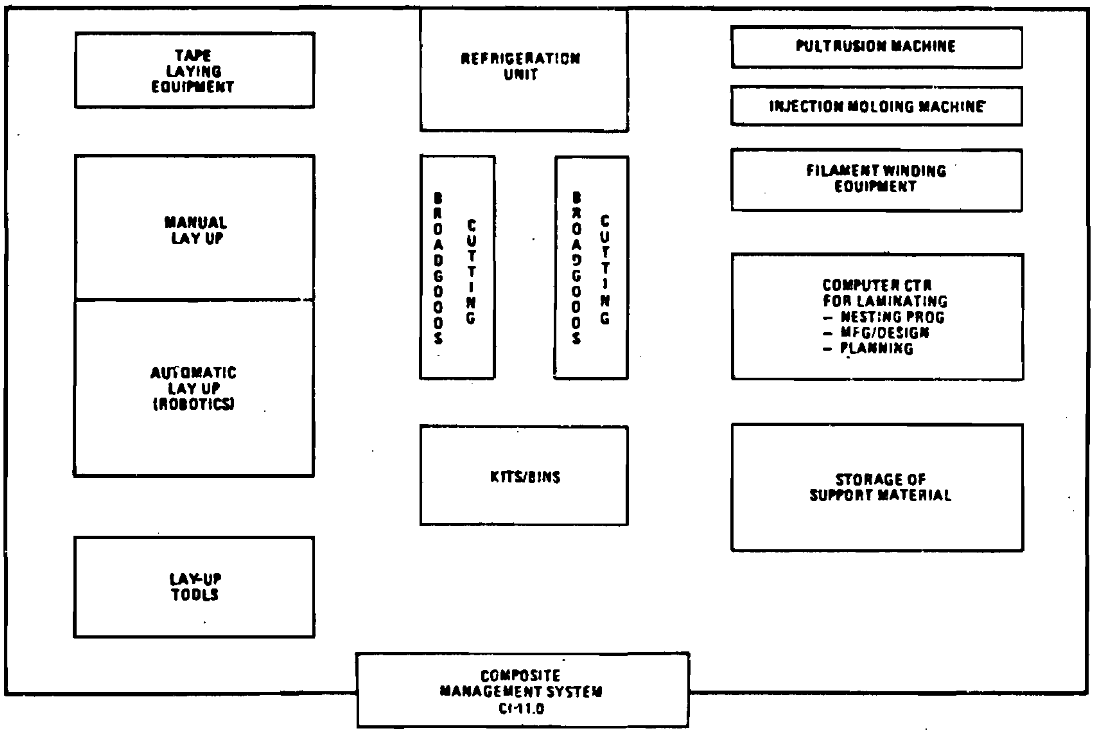


Figure 3-35 Implementable Configuration Items for the Generic Lamination Cell

PHASE	PLAN/CONCEPTS		CONTRIBUTION
DESIGN AND PLAN	• SYSTEM DESIGN - DIAGNOSTIC - GENERAL BUSINESS ISSUES - ENVIRONMENT	o IMPLEMENTATION PLAN - SCHEDULES - TASKS - RESPONSIBILITIES	o OBJECTIVE • STRUCTURE • COMMITMENT o MEASUREMENT
IMPLEMENT	• PARTICIPATION - EXECUTIVE - PROJECT REVIEW TEAM - FUNCTIONAL IMPLEMENTATION TEAMS o TRAINING - COURSE DEVELOPMENT - MANAGEMENT/NON-MANAGEMENT - EVALUATION	• PROCEDURES - MANUAL - AUTOMATIC - CELLS/SYSTEMS o TESTING - ACCEPTANCE - FUNCTIONAL - INTEGRATION	• COMMUNICATIONS • USER INPUTS o COORDINATION o DIRECTION o UNDERSTANDING o LEADERSHIP o RESPONSIBILITY
CONTROL AND MAINTAIN	o INSTALLATION/INTEGRATION - START OPERATION - EVALUATION - OPERATIONAL PHASE	o DOCUMENTATION - CELLS - SYSTEMS - INTERFACES	o SUSTAINABILITY o MAINTENANCE o MEASUREMENT o AUDIT o TRACKING o PERFORMANCE

Figure 3-36 Implementation Plan/Concepts

Because the autoclaves and refrigeration units are extremely difficult to move, consideration of their permanent location must take place early in the preliminary design of the ICC. Other equipment can be moved and is not as constrained as these two items. Implementation activities required to complete the preliminary design of the "TO BE" ICC are:

- o Procurement
- o Site-preparation and facilities
- o Installation of laminating cell
- o Installation of bagging cell
- o Installation of curing cell
- o Installation of trim and drill cell
- o Installation of test and inspection cell
- o Installation of subassembly cell
- o Installation of rework cell
- o Installation of tool prepared and quick-fix cell
- o Installation of material handling system
- o Installation of design/planning interface
- o Installation of the generic ICC Management System.

The Implementation Plan Strategy document (IP110511000) dated 31 October 1983 was submitted to the Air Force on 31 October 1983 defines all the subtasks involved under the thirteen items listed above (the reader is referred to Volume III Part 10 of this report).

NORTHROP'S IMPLEMENTATION PLAN STRATEGY

Northrop's Implementation Plan Strategy address specific implementation steps to be taken, responsible organizations and planned time-phasing. It identifies and minimizes risks prior to implementation. The "TO BE" system will develop through a series of phases.

- o Phase Zero - Detail design, construction, test
- o Phase One - Facilities preparation
- o Phase Two - System conversion
- o Phase Three - Organizational and procedural changes
- o Phase Four - Training
- o Phase Five - System installation and performance monitoring

Northrop has chosen a 3-level strategy for its ICC development and execution. This conceptual structure is shown in Figure 3-37. Figure 3-38 illustrates Northrop's 3-tier organizational structure which will be used to manage the implementation of the system.

Northrop intends to use each of its three divisions' (Northrop Aircraft, Northrop Advanced System, Northrop Ventura) sites to study the cells and system to be implemented. Those with the greatest potential will be selected for ICC development.

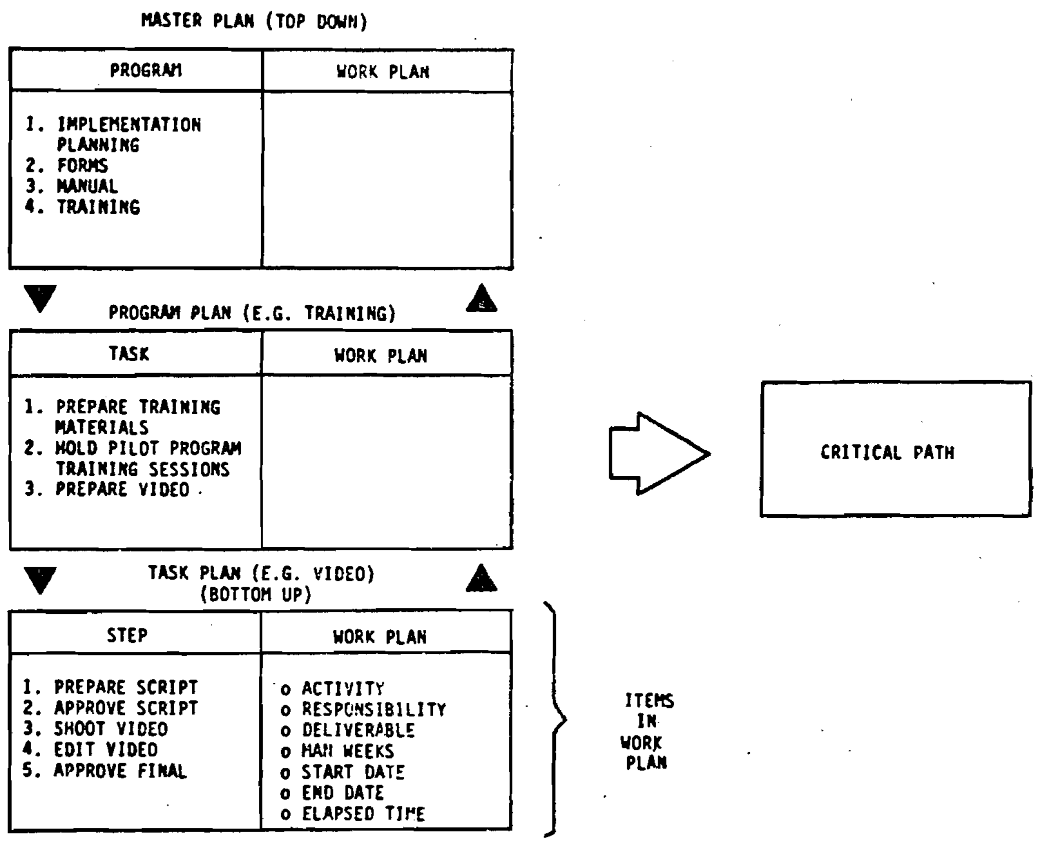


Figure 3-37 Three Level Implementation Strategy

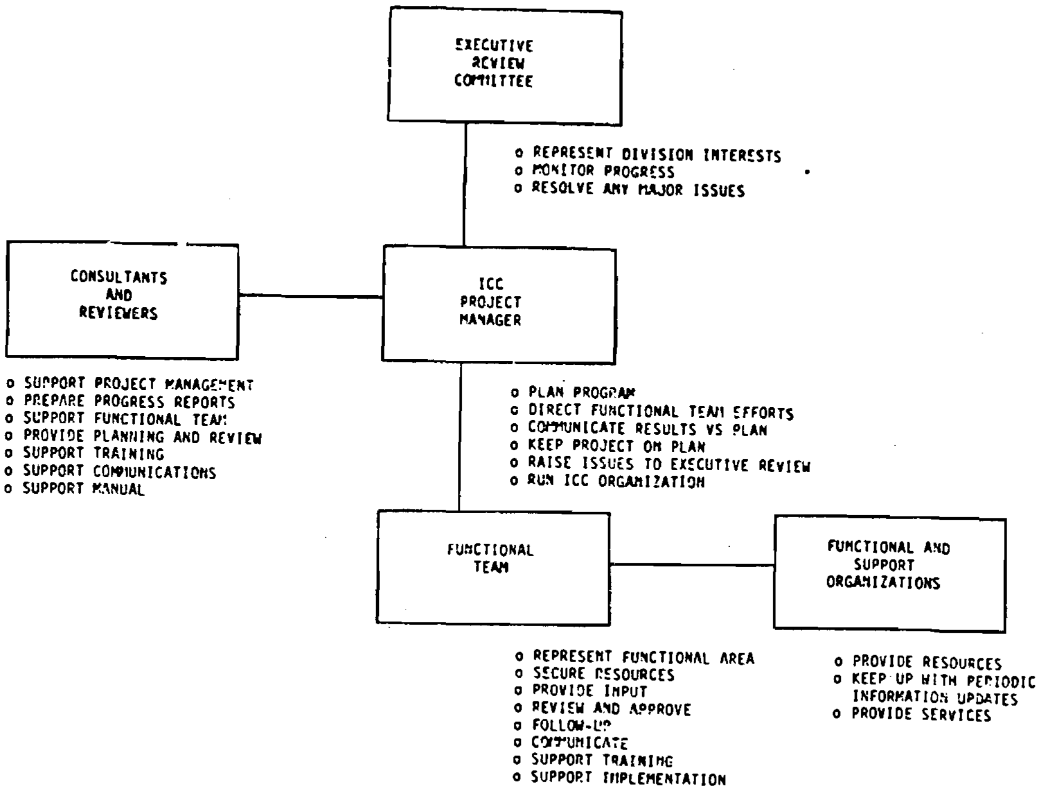


Figure 3-38 ICC Implementation Organizational Structure

The ICC project team will develop a facility plan which will identify the site location, computers, equipment, communications network and fixtures to be installed. It will also establish appropriate time tables and resource requirements.

Northrop has developed a logical schedule of a transition plan to convert its "AS IS" composites manufacturing system to its "TO BE" system. This schedule is shown in Figure 3-39. It identifies all the activities which must take place from preparing the ICC facility to the dismantling of the old system. Each of these items is explored in detail in Appendix A of the IP110511000 document of 31 October 1983.

VOUGHT'S IMPLEMENTATION PLAN STRATEGY

Vought's ICC Implementation Plan is a generalized framework that provides a roadmap for implementation and makes a clear statement of priorities. This plan, shown in Figure 3-40, is organized in three phases. Each phase is broken down into tasks to focus attention on the items which have the greatest impact. It also provides a tentative schedule for the tasks to be accomplished in order to implement a near-term system.

This plan is based on the ICC as described in the Development Specification document and uses the facilities and major equipment currently in place at Vought. The approximate time frame for scheduling the tasks under each of the phases will be revised to include more detail as the detail designs are finalized.

Each of these scheduled items is discussed in detail in Appendix B of the IP110511000 document of 31 October 1983.

GENERAL DYNAMICS IMPLEMENTATION PLAN STRATEGY

The System Specification document provided the basic strategy for developing the ICC at General Dynamics. The System Design Specification expanded that scope by identifying the individual necessary technologies and showing how they will interact within the ICC systems. The Development Specification identified those systems and technologies that needed development prior to their implementation. The System Test Plan provided a strategy for testing all of the systems technologies that were to be implemented in General Dynamics ICC.

Figure 3-41 illustrates, in outline form, the overall schedule of the implementation and an item description, in chronological order, of the systems and technologies being implemented. All implementation will be accomplished through the coorindation and cooperation of the affected departments. Sheet 2 of Figure 3-41 is an example of the tasks to be accomplished who has the responsibility for accomplishing each task, date of start and completion and pertinent comments concerning each task.

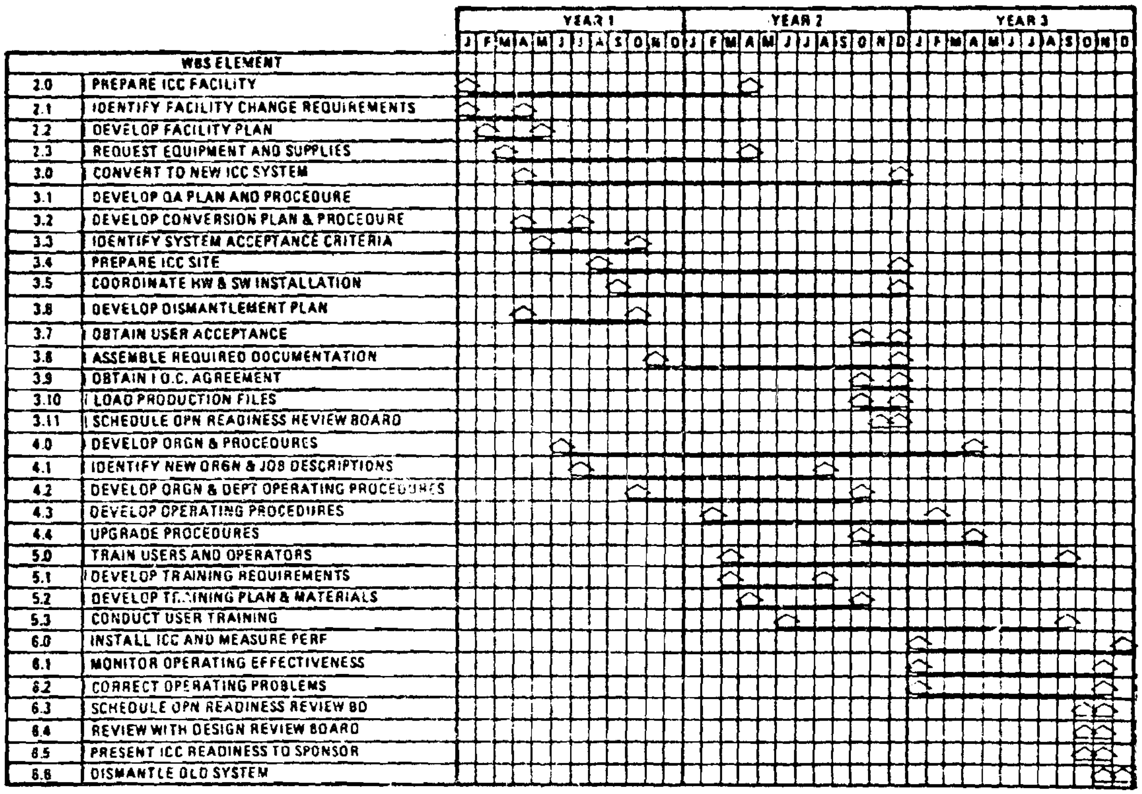


Figure 3-39 Northrop ICC Implementation Schedule

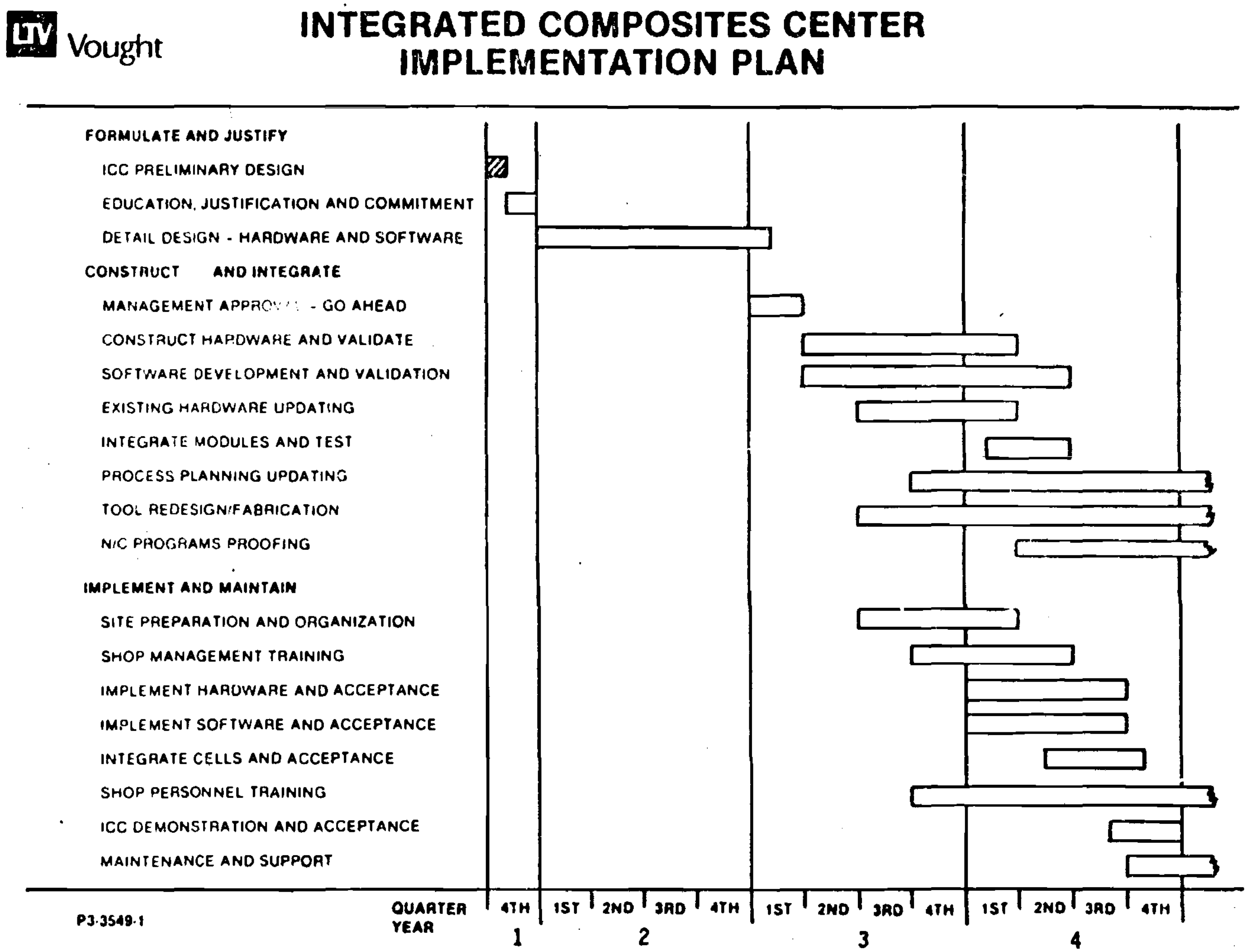


Figure 3-40 Vought ICC Implementation Plan

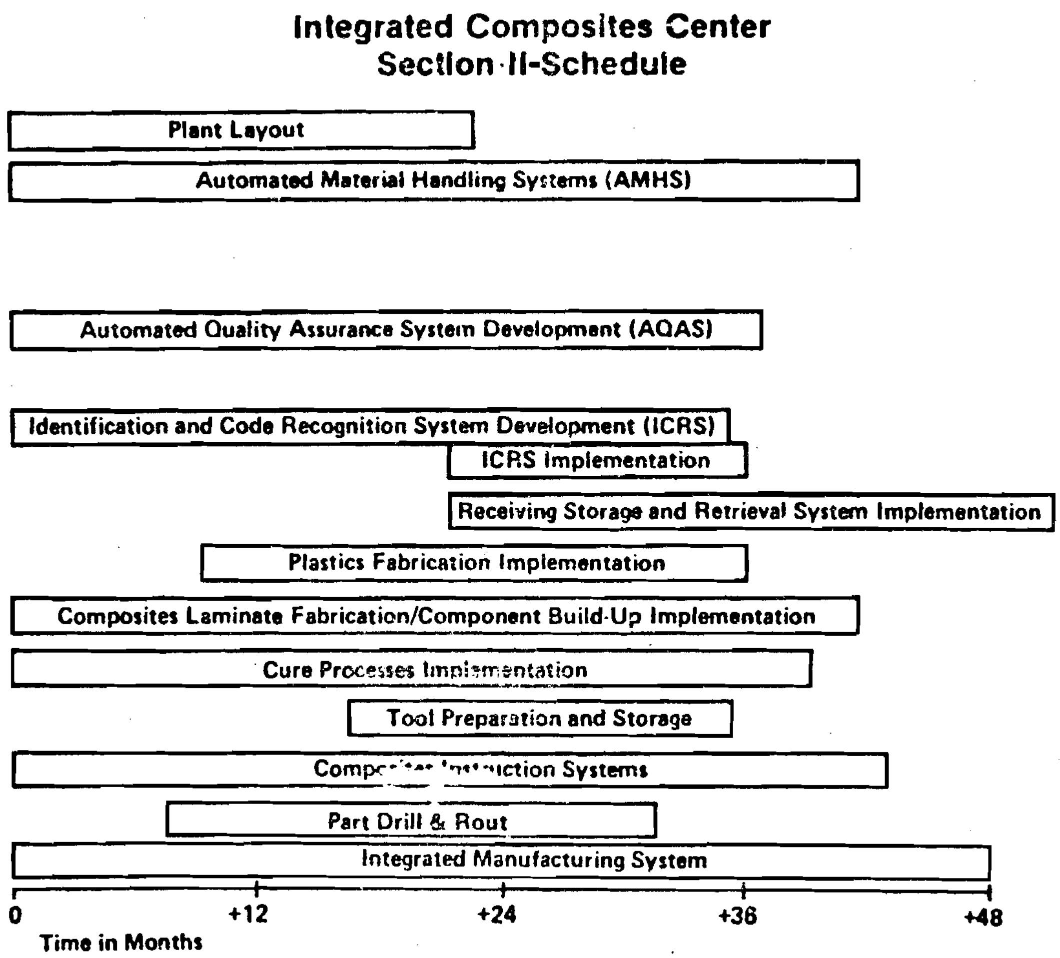


Figure 3-41 GD/FW ICC Implementation Schedule
(Sheet 1 of 2)

ICC DETAILED IMPLEMENTATION PLAN

TASK	RESPONSIBILITY	DATE	COMMENTS
2. Plant Lay-Out			
A. Composite Manufacturing center lay-out philosophy	Division and Corporate Management	0	This decision will set the ground rules for all implementation efforts.
B. Coordination of ICC lay-out	Team leader	0+6	Gather data and present lay-out plans to various management groups with support from shop floor upper management.
C. Prepare detailed ICC lay-out	Facilities Planning	0+6	Facilities Planning will produce a detailed ICC lay-out to reflect the philosophy set by upper management using data from the team leader.
D. Coordinate with affected departments	Team leader	0+6	The team leader will interface with the affected production departments in regards to the new lay-out.
E. Implement ICC Plant lay-out	Facilities Planning Team leader	+6+20	Facilities will implement the ICC plant lay-out with coordination assistance from the team leader.
3. Integrated Manufacturing System for	Team leader	0+48	The team leader will coordinate the implementation of the IMS with the other systems with in the ICC.
A. Cell Control System	IMS team and team leader	0+48	The IMS team will interface the cell controller to the cells within the ICC.

Figure 3-41 GD/FW ICC Implementation Schedule (Sheet 2 of 2)

3.3.8.6 Establish Integrated Composites Center System Test Plan (WBS 4.3.8.6)

This document describes the concepts, criteria, standards, tools and strategies for testing the ICC at the cell or system level. the plan includes the Development Testing and Evaluation (DT&E) of the system as well as strategies for installation, checkout and technical demonstrations. It also addresses the validation of the users, operators, and maintenance manuals.

The plan describes the types of tests to be conducted, basic test sequences and the broad test objectives required to fulfill ICAM Documentation Standards and to maintain continuity with previous submitted documents.

The System Test Plan for the ICC Preliminary Design Concepts (generic ICC) is a general plan encompassing each of the eleven major Configuration Items (CIs) and significant subordinate configuration items which were presented in the System Specification (SS). It is based on the requirements delineated in the System Requirements Document (SRD). A design strategy for each configuration item was presented on the System Design Specification (SDS). Hardware and software specifications were defined in the Development Specification (DS).

The eleven Configuration Items presented in the Test Plan are:

- o Composite laminating cell
- o Composite bagging cell
- o Composite curing cell
- o Composite trim and drill cell
- o Composite test and inspection cell
- o Composite subassembly cell
- o Composite rework cell
- o Tool preparation and quick-fix cell
- o Material handling system
- o Design/develop composite structure
- o Composites management system

Figure 3-42 illustrates the Configuration Item Test flow and Figure 3-43 shows a Functional Test Flow. Figure 3-44 shows a block diagram identifying the major cells and systems in the ICC.

The primary objective of the System Test Plan was to determine if the ICC system could fabricate and build composite laminates or subassemblies that meet or exceed design requirements. Also, various manuals would be developed during the Preliminary Design Phase and continually updated through the entire ICAM Life Cycle. These manuals are prepared by the vendor/supplier to provide relevant information on delivered hardware items. The Users' Manual is a primary reference document describing the developed functions in basic user-oriented terminology. The Operators' Manual is a computer software document describing the commands of all the operating systems for both the cells and the composite

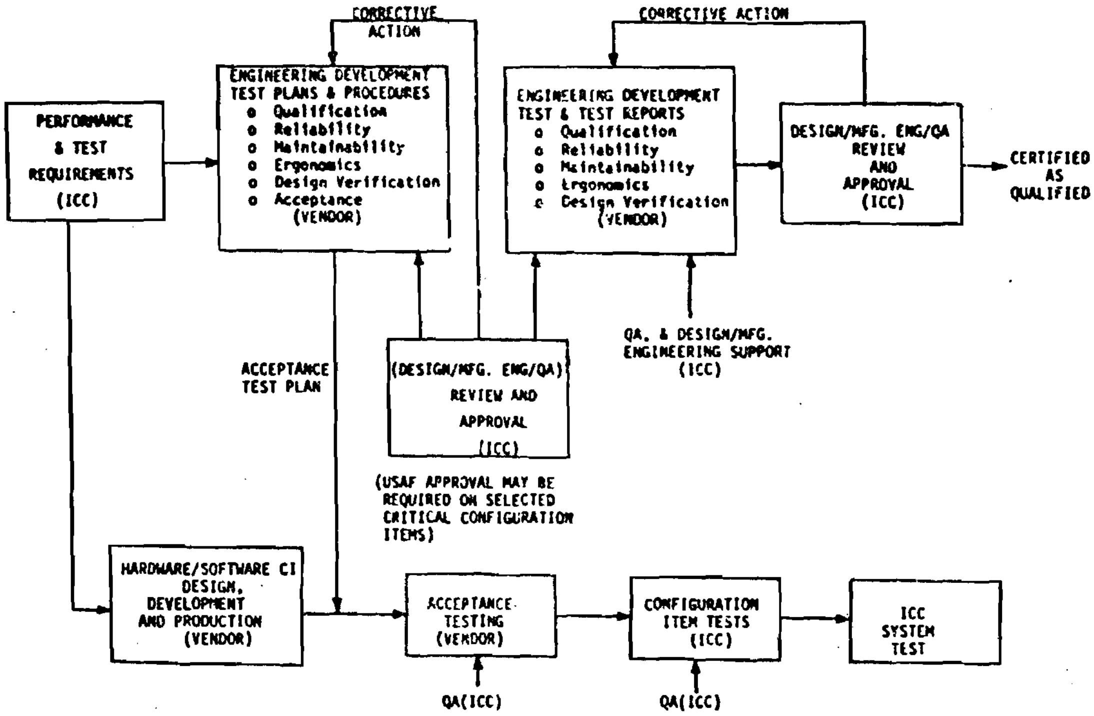


Figure 3-42 Configuration Item Test Flow

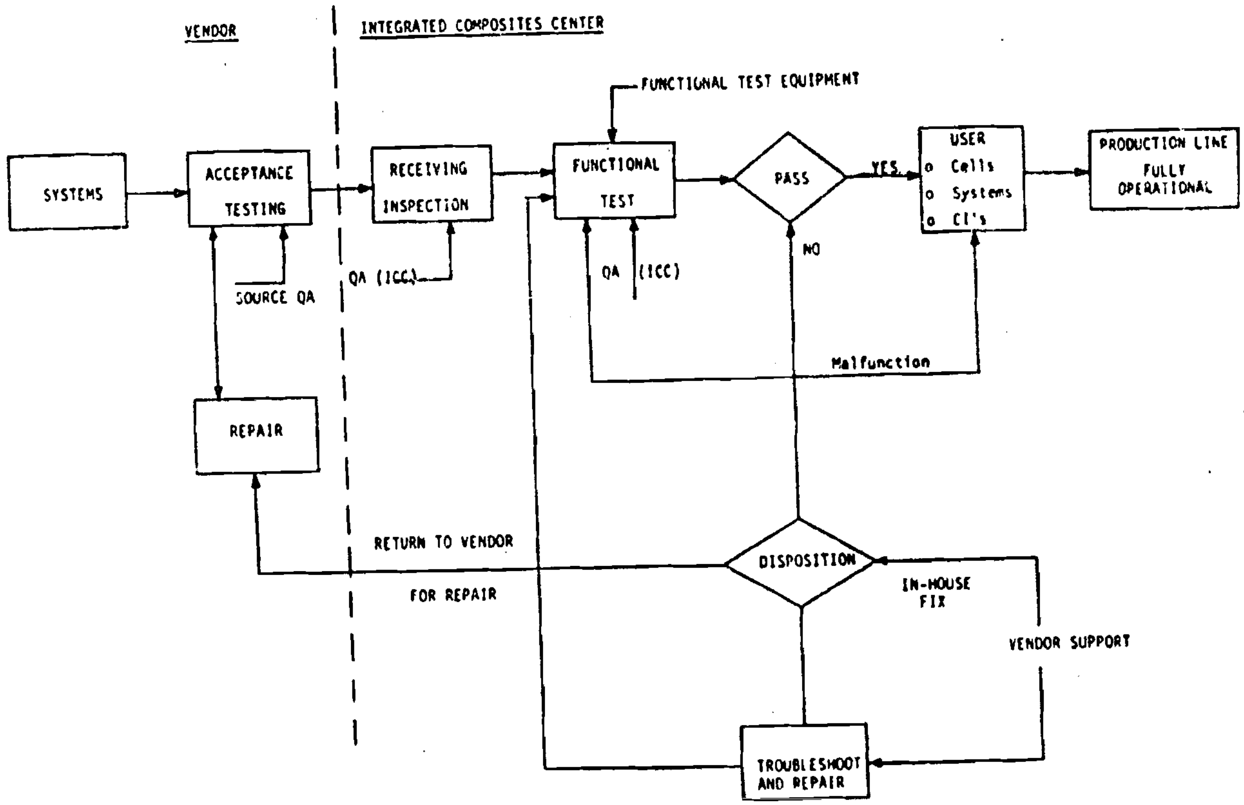


Figure 3-43 Functional Test Flow

ICC LAYOUT
GENERIC CONCEPT

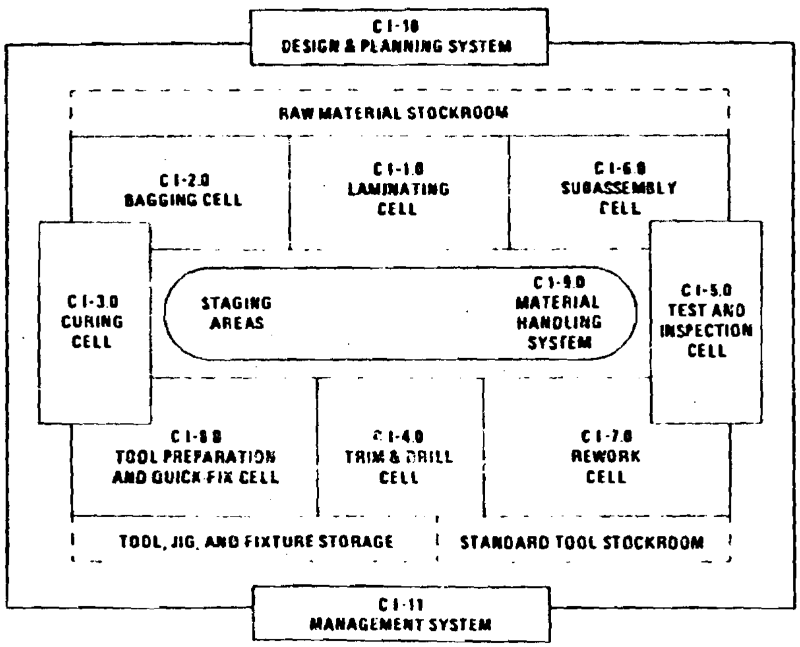


Figure 3-44 Block Diagram of Test Program for Generic ICC by Prime Configuration Items (Not to Scale)

management system. The Maintenance Manuals provide technical information for understanding the configuration item, the operating environment and preventive maintenance procedures.

The System Test Plan Strategy (STP110511000) dated 31 August 1983 submitted to the Air Force describes in depth specific test plans for the major configuration items listed at the beginning of this paragraph and illustrated in Figure 3-44. The reader interested in details is referred to Volume 3, Part 8 of this report.

3.3.8.7 Produce Configuration Item Identification (WBS 4.3.8.7)

The Development Specification decomposes specific configuration items' requirements to a level sufficient to enable the evolutionary development of a detail design. It also identifies interfaces that will be accommodated by the subsequent design of the configuration item.

The preliminary Development Specification, document number 110511000, which was submitted to the Air Force on 30 June 1983, was published as two separate documents. The basic book describes specifications for a generic Integrated Composites Center. The second document, in the form of Appendices, contains specific information concerning Northrop's, Vought's and General Dynamics ICC. In addition, the Appendices contain General Electric's Plans and Control Composites and It's Relationship to Control Centers.

The basic book details the following information:

o The functional requirements for each Configuration Item as extracted from the System Design Specification
o The performance requirements that will normally be verified during the testing phase
o The physical characteristics that each Configuration Item should exhibit
o The principal interfaces between the Configuration Item being specified and other Configuration Items with which it must be compatible
o The design constraints that each Configuration Item must adhere to in order to satisfy the preliminary design requirements.

The specifications for each Configuration Item are the results of the investigation analysis performed for the System Requirements Document, the feedback generated by the System Requirement Review, the elaboration and validation of these requirements as presented in the System Specification and the design strategy conceptualized in the System Design Specification.

Northrop established certain major groundrules to provide the foundation of the Development Specification. They were:

o The ICC will use only fiberglass, Kevlar and carbon or graphite fibers with expoxy, polyimide and bismalermide matrices as composites materials and hybrids
o Bagging will continue to be required

- The autoclave or similar heat/pressure vessels will be the principle curing medium for primary aircraft structures
- No substantial reduction in trimming and drilling will occur
- There will be no appreciable degradation of the role played by quality assurance.
- Increased emphasis will be placed on the manner a cure composite part is handled
- Quality of work life will be present at ICC startup
- Shop floor and manufacturing control systems will grow in importance
- Fiber-reinforced, metal-matrix composites are excluded from consideration because of their current sensitivity with respect to applications and processing technology
- Final assembly or installation of a component or structure on an airframe is not considered part of the ICC.

The ICC coalition concentrated on eleven cells or systems (Configuration Items) that encompass the entire gamut of composite fabrication and subassembly. The major Configuration Items are shown in Figure 3-44. Each of these items have subordinate CIs. Figure 3-45 illustrates a process flow diagram for the ICC with emphasis placed on the Composites Management System.

In this Development Specification, the coalition examines the major benefits to be derived from implementing the ICC. They are twofold. The first being the optimum use of scarce resources in the areas of facilities, labor, capital equipment, raw materials and management ability. The second is in the production of composite structures that are cost competitive and embody structural integrity.

In addition to these advantages, there are also several drawbacks to the ICC, such as:

- The inherent risks associated with implementing unproven technologies
- The inability to accurately estimate or forecast costs of brick and mortar and limited off-the-shelf technologies superimposed on over-the-horizon technologies
- The possibility of insufficient manufacturing flexibility
- The risks associated with making engineering acceptable parts with "TO BE" technologies.

The major system requirements presented in the System Specification Document have been transferred into individual Configuration Items (Figure 3-46) representing both cells and systems indigenous to the ICC. These Configuration Items are fully developed and described in the Development Specification, DS110511000, 30 June 1983. Each of the major CIs have subordinate CIs which are delineated to the maximum extent possible in DS110511000. For precise design details, the reader is referred to Volume 3, Part 9.

For the purposes of this final report, only a brief description of each CI is provided in the following paragraphs together with an illustration which depicts major breakouts under each item.

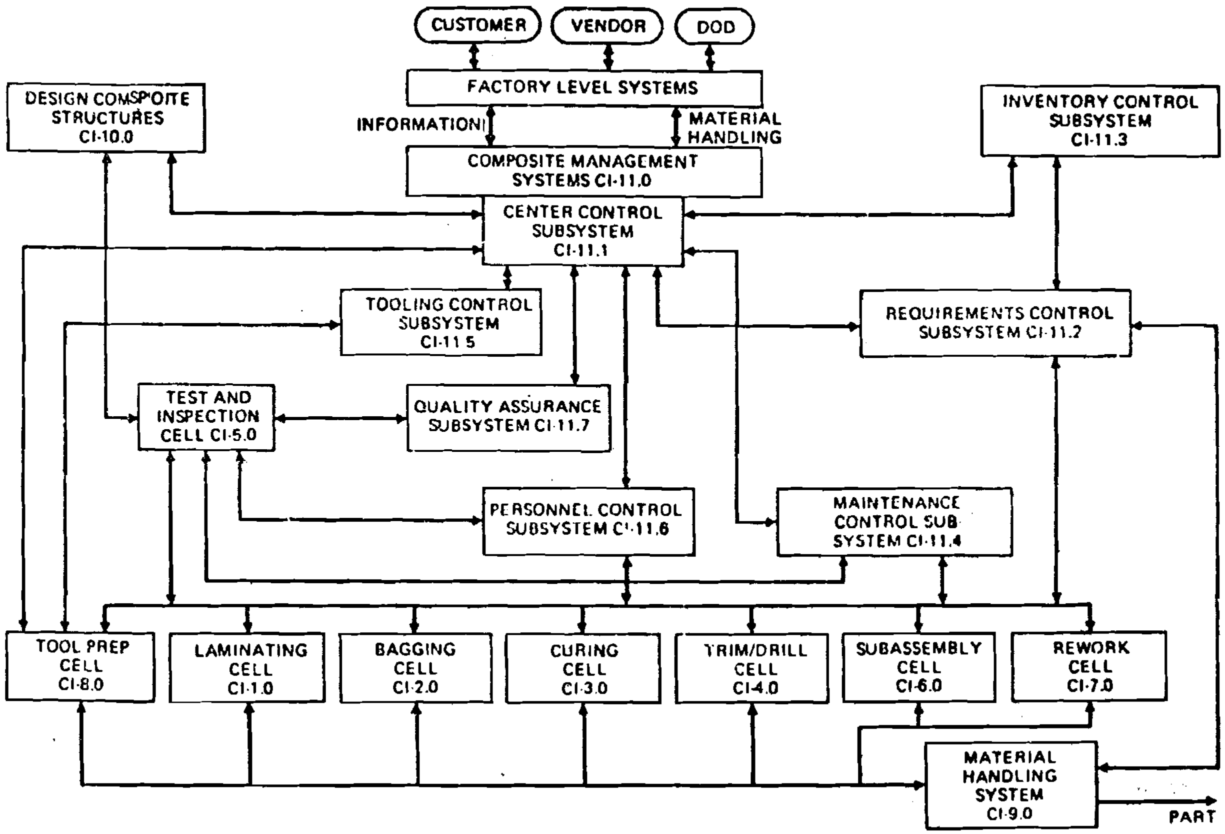


Figure 3-45 Process Flow Diagram

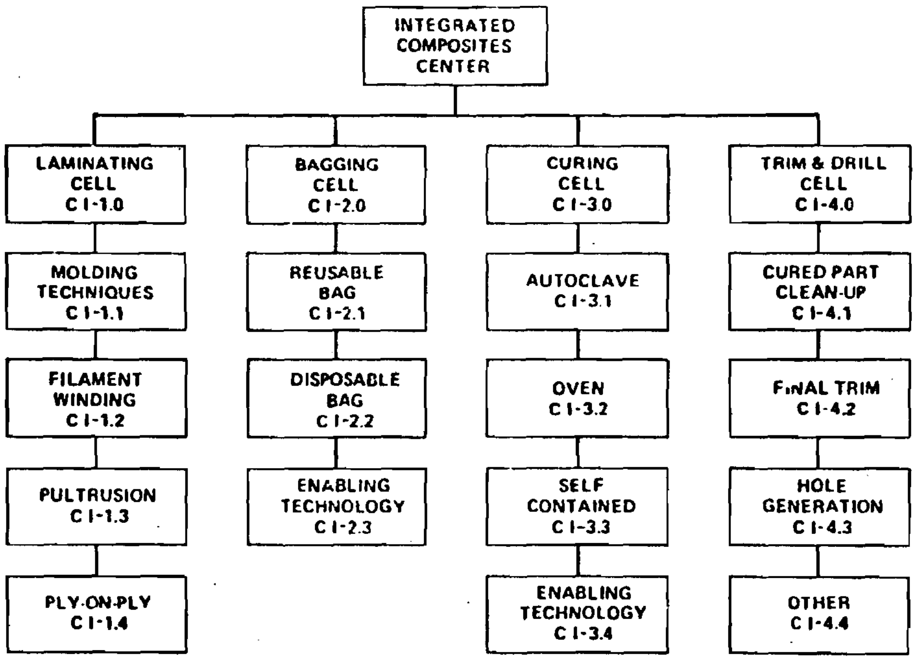


Figure 3-46 Specification Tree Indicating the Major Configuration Items in the "TO BE" Integrated Composites Center

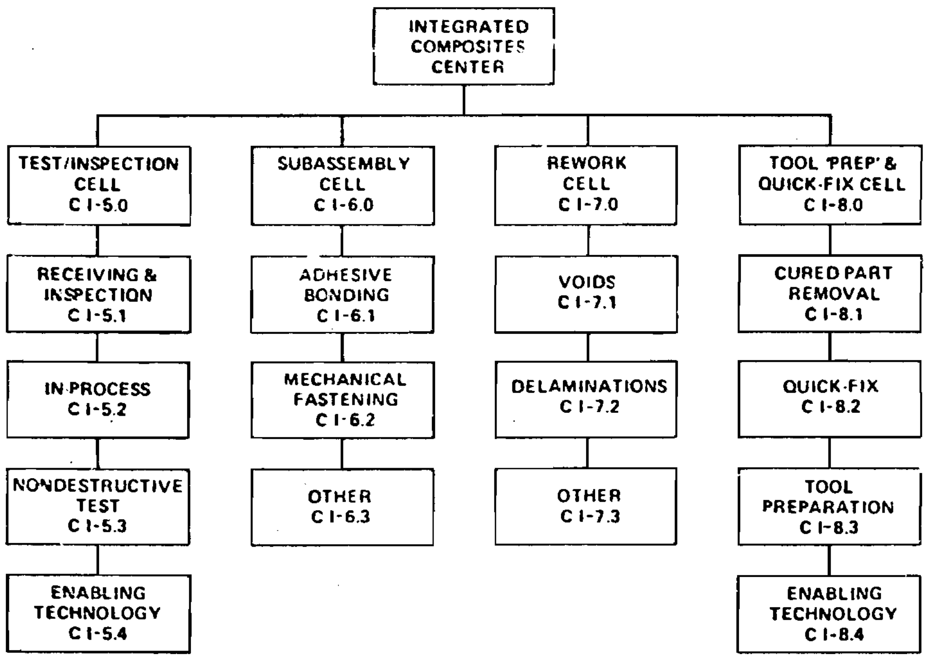


Figure 3-46 Specification Tree Indicating the Major Configuration Items in the "TO BE" Integrated Composites Center (Continued)

Composite Laminating Cell (Configuration Item 1.0)

Laminating is the process by which a composite detail part or structural component is fabricated or formed via the placement or build-up of one lamina (a single ply or fiber) superimposed on another until the required density is achieved. The Development Specifications for the "TO BE" laminating cell includes the ability to accommodate various composite materials to fabricate and subassemble many different parts, structures and shapes for both fighter-type and transport-type aircraft. Figure 3-47 presents a generic laminating cell which exhibits all of the laminating techniques that are to be resident in that cell. Figures 3-48 and 3-49 illustrate the break out of subitems within the main configuration item 1.0.

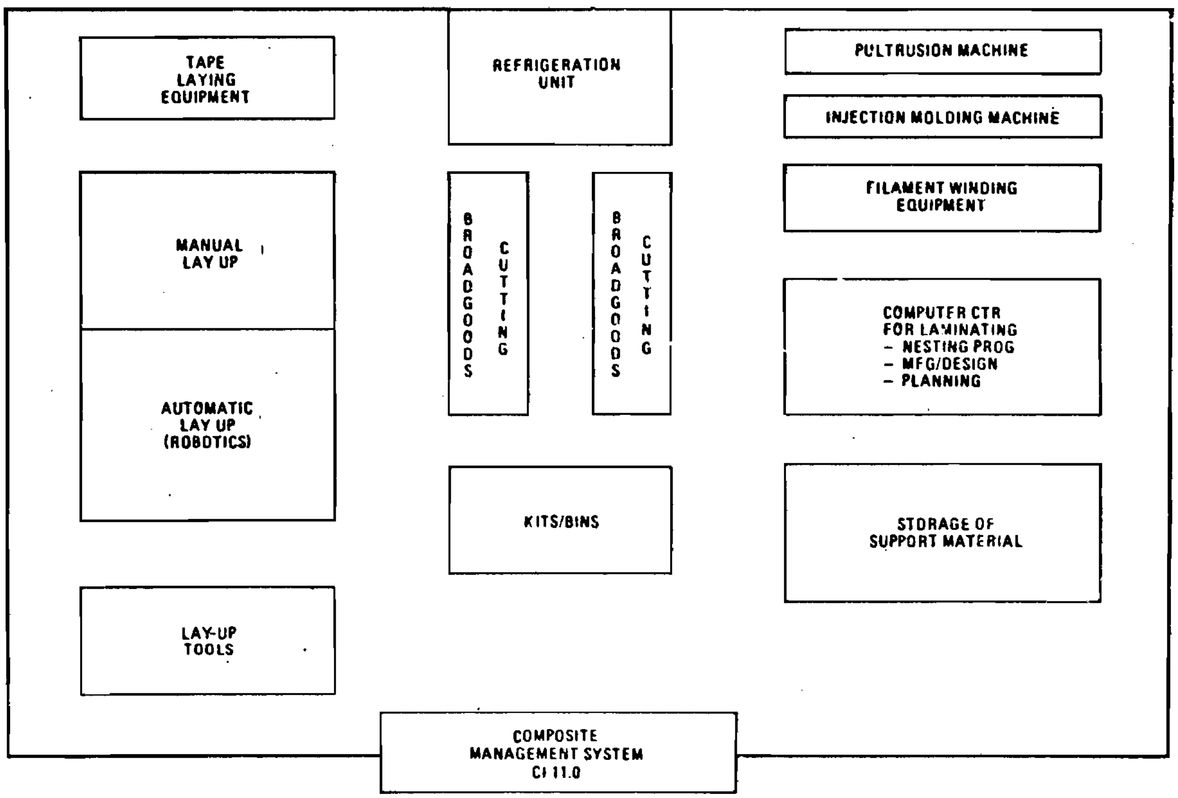


Figure 3-47 Generic Laminating Cell

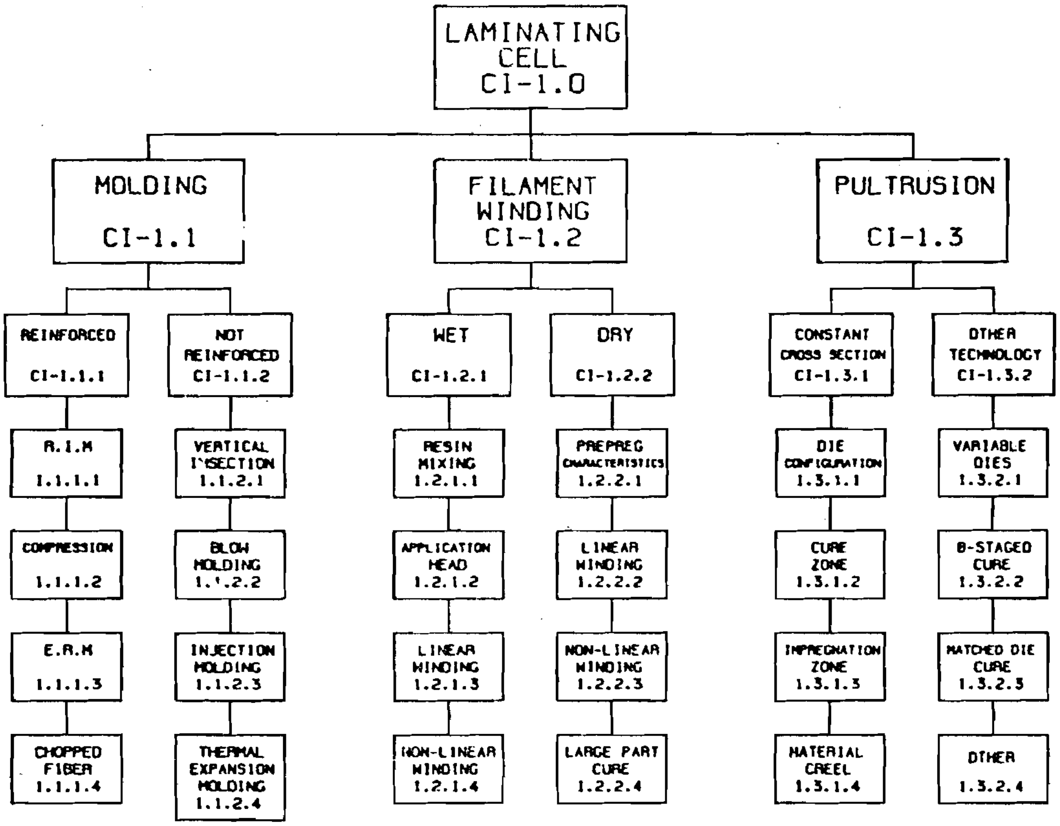


Figure 3-48 Laminating Cell Configuration Items

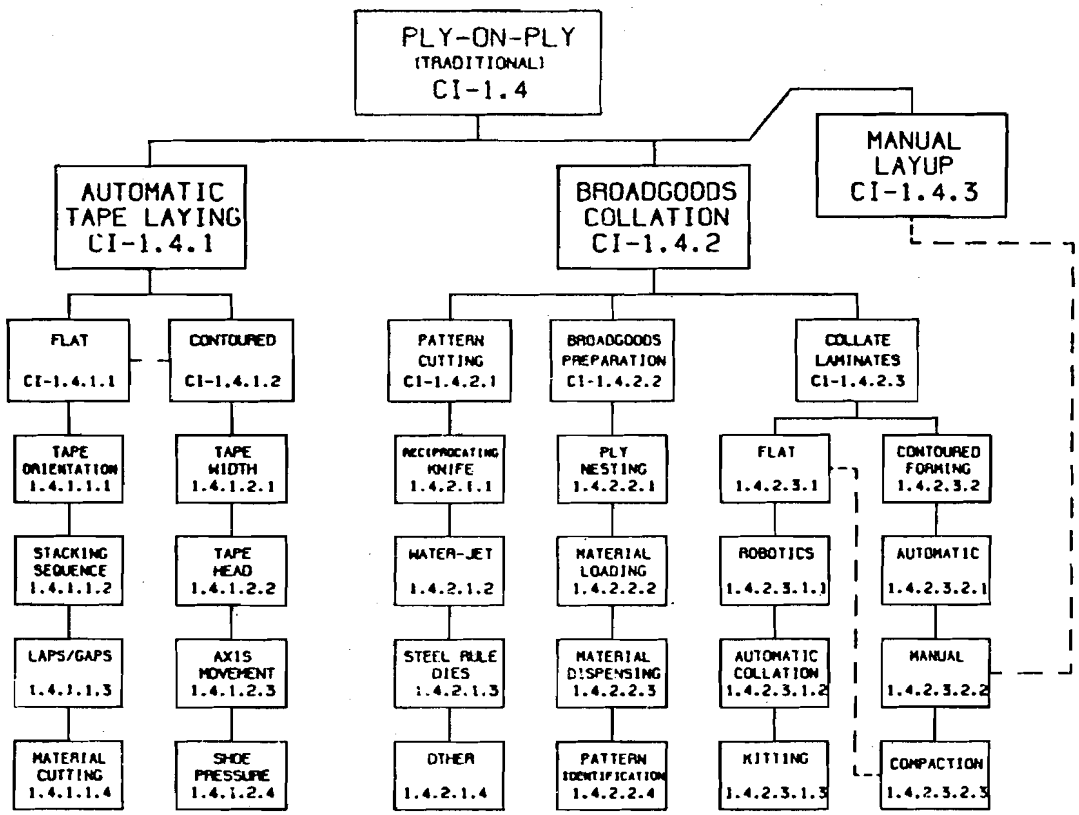


Figure 3-49 Ply on Ply Configuration Items

Composite Bagging Cell (Configuration Item 2.0)

Bagging is the process by which an airtight membrane is placed over the completed laminate or subassembly allowing a vacuum to be pulled and external heat and pressure to be applied. Material employed for this operation is nylon film (or comparable material) disposable bags or reusable silicone rubber bags. Figure 3-50 illustrates a specification tree that identifies the major Configuration Items which are resident in the Bagging Cell.

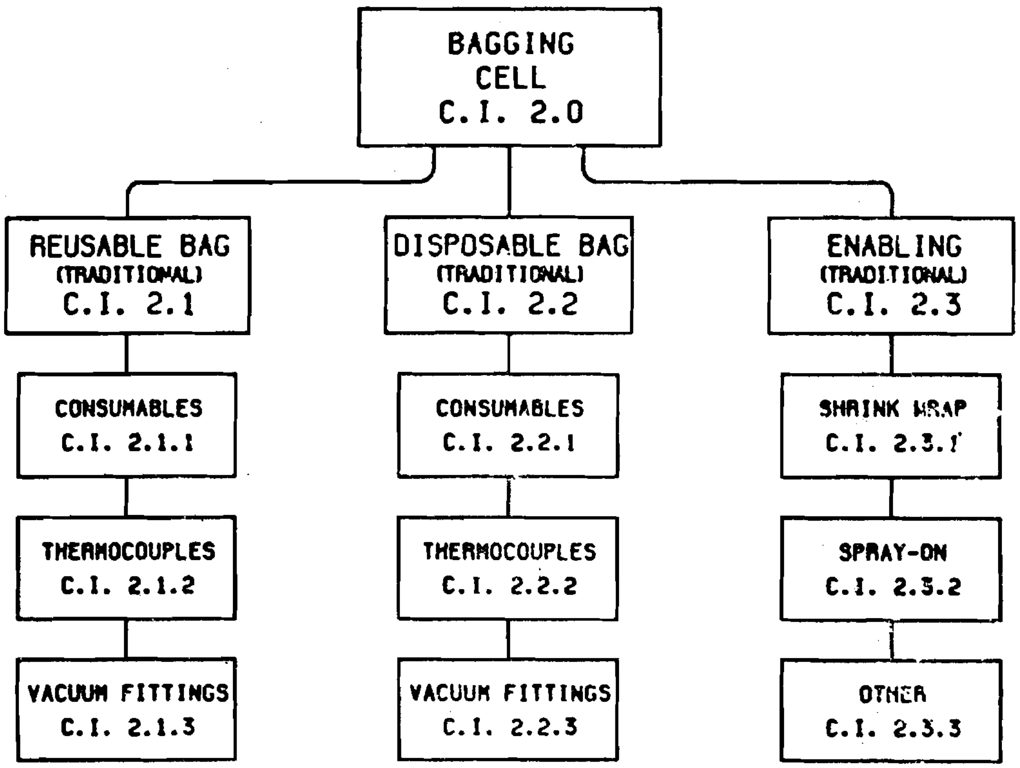


Figure 3-50 Specification Tree of the Bagging Cell

Composite Curing Cell (Configuration Item 3.0)

After the laminate has been bagged on its curing or bonding fixture in the bagging cell, it is moved to the cure staging area. It is the function of the curing cell to subject the bagged component to heat and autoclave (or vacuum) pressure. The heat may be generated by an oven (a vessel that provides heat by convection), by an autoclave which provides both heat and pressure or by other heat/pressure vessels. This curing process allows the organic matrix to gel and set. A post-curing process may also lie within the curing cell to enhance the structural properties in the laminate or subassembly. Figure 3-51 identifies the major configuration items within the curing cell.

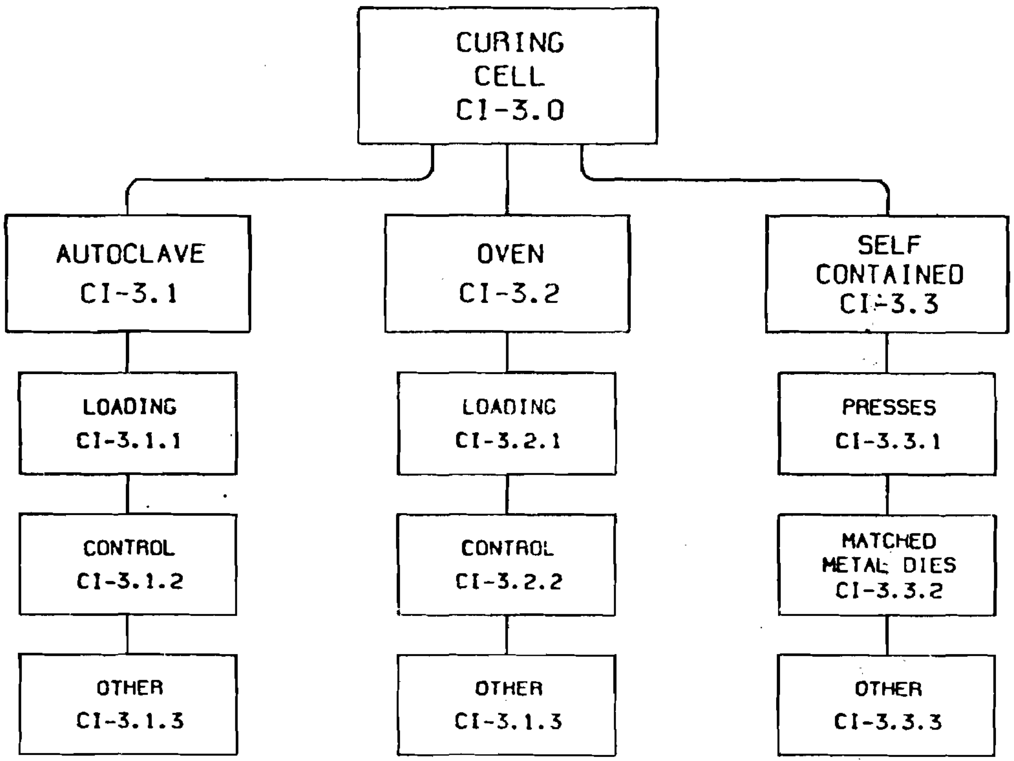


Figure 3-51 Specification Tree - Curing Cell

Composite Trim and Drill Cell (Configuration Item 4.0)

After the cured composite laminate is removed from the curing cell, it is transported to the Trim and Drill Cell. Within the trim and drill cell, excess composite material will be removed. Cutouts may also be required to accommodate additional detail parts for consolidation into the subassembly cell. In addition to peripheral trimming, hole preparation occurs in this cell. These hole preparations will primarily include drilling, countersinking, reaming and counterboring. Figure 3-52 identifies the major configuration items within the trim and drill cell.

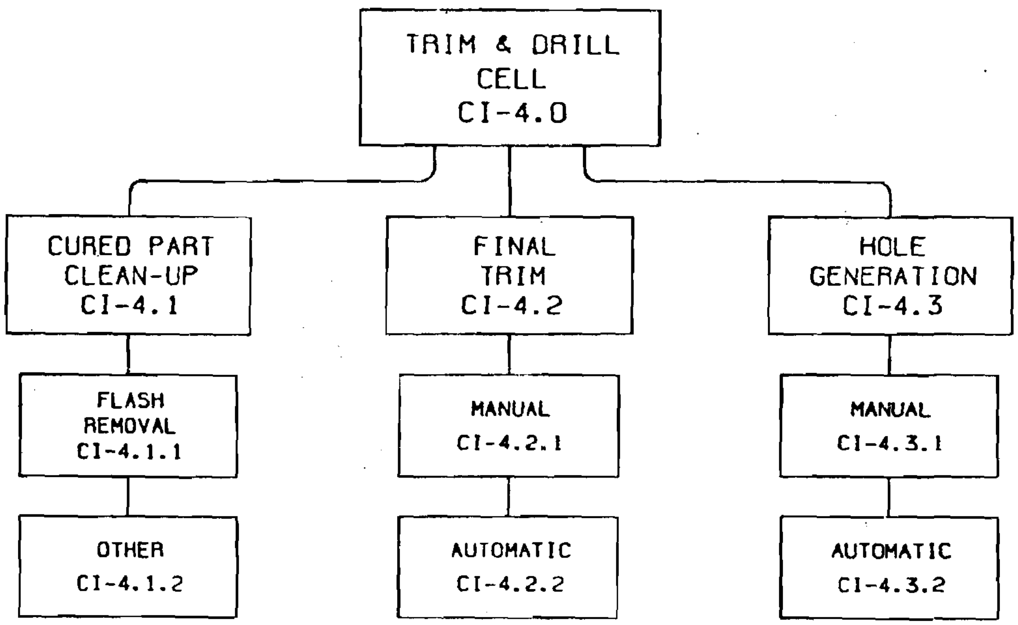


Figure 3-52 Specification Tree - Trim and Drill Cell

Test and Inspection Cell (Configuration Item 5.0)

The Test and Inspection Cell will perform initial receiving and inspection tests on incoming raw material to ensure it was shipped in the right environment and that is meets all specifications of the purchase order. The primary activities of this cell will be nondestructive testing, nondestructive evaluation, and nondestructive inspection to ensure the structural integrity of the composite structure and to identify structures that require rework. Figure 3-53 identifies the major configuration items within the test and inspection cell.

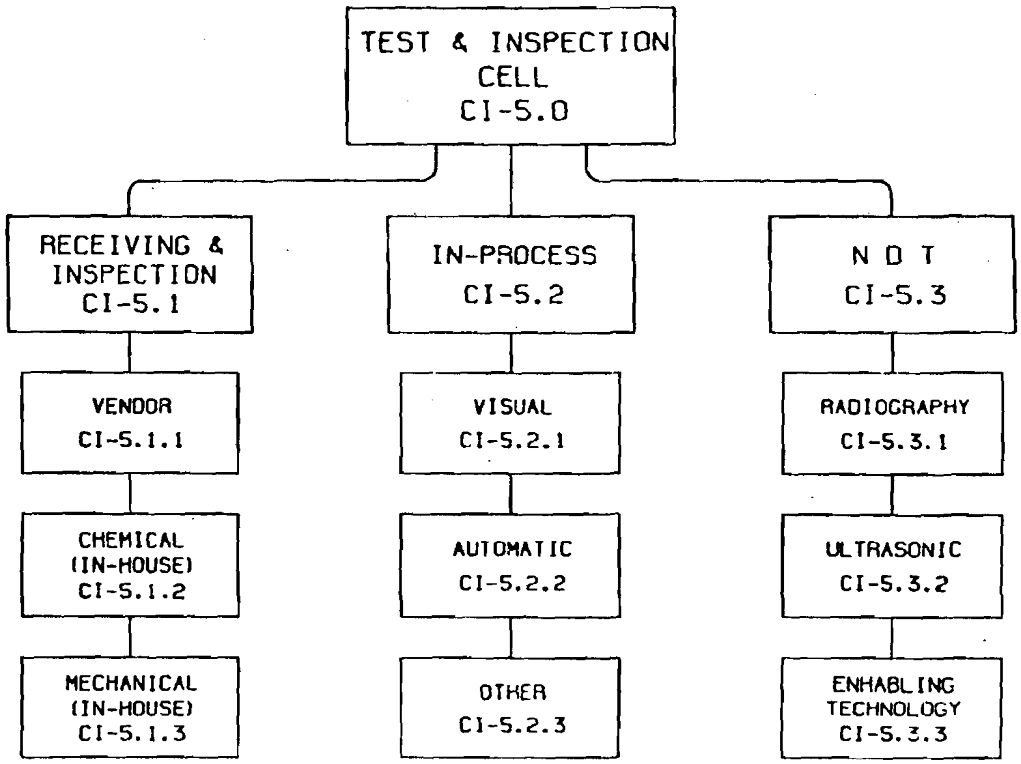


Figure 3-53 Specification Tree - Test and Inspection Cell

Composite Subassembly Cell (Configuration Item 6.0)

The function of the subassembly cell is to join or combine two or more detail parts to produce a higher level or more complex structure, i.e., a subassembly. Typical detail parts would include all types of honeycomb, various metallic parts and cured composite parts and laminates. The operations or processes would primarily center around the adhesive bonding and mechanical fastening activities. Figure 3-54 identifies the major configuration items within the subassembly cell.

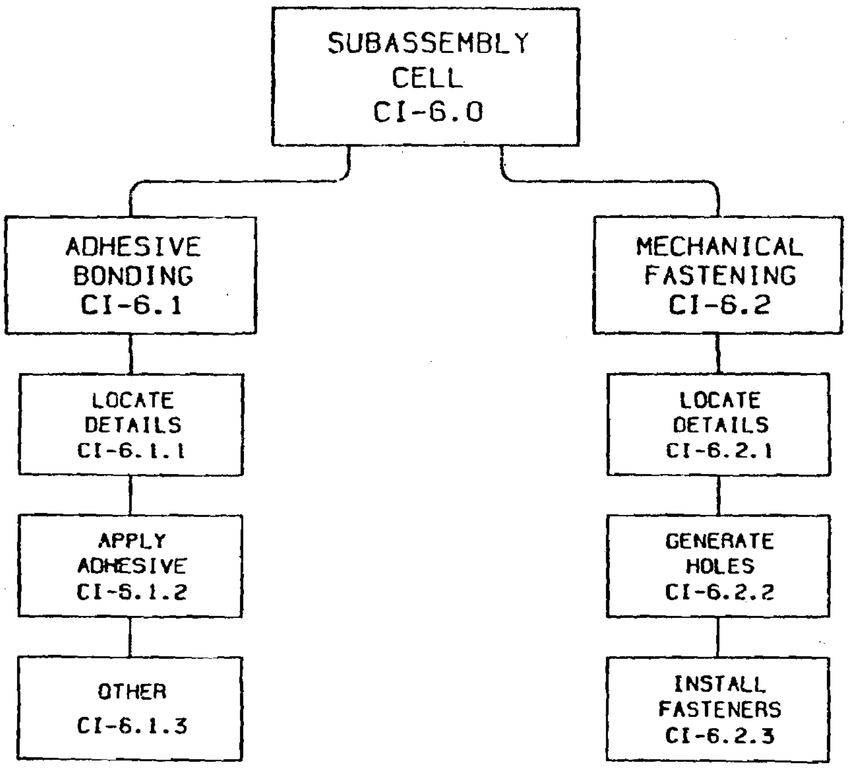


Figure 3-54 Specification Tree - Subassembly Cell

Composite Structure Rework Cell (Configuration Item 7.0)

The part rework cell has the function of bringing laminates, detail parts and subassemblies that have been rejected up to standard for subsequent buyoff in the test and inspection cell. Major problems in laminates will be edge delaminations or disbands and surface scratches, reworking voids and attachment holes. This cell could be construed as one that does customized work since no two reworks will be exactly the same. The amount of work flowing through this cell depends upon how good or how bad other cells in the center are functioning. Figure 3-55 identifies the major configuration items within the structure rework cell.

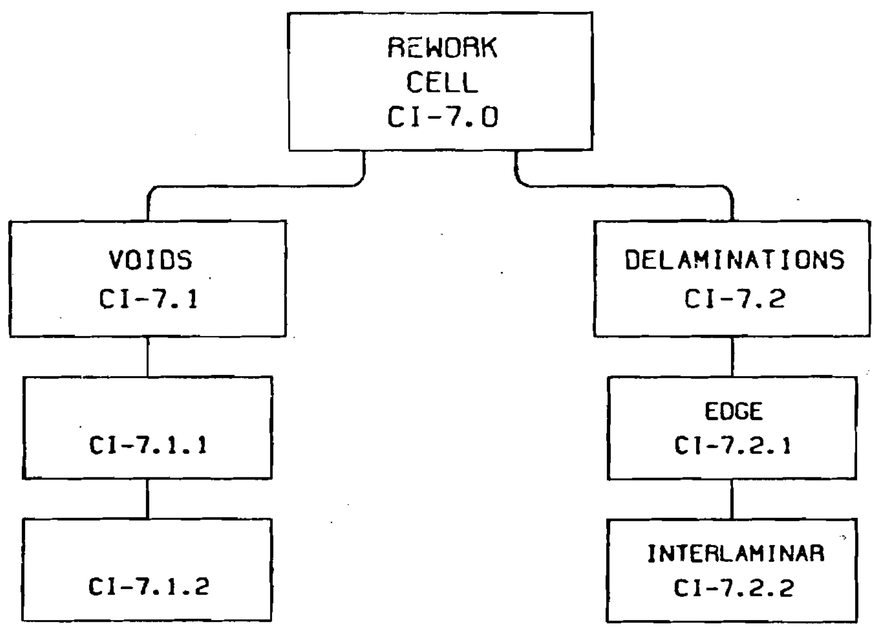


Figure 3-55 Specification Tree - Rework Cell

Tool Preparation and Quick-Fix Cell (Configuration Item 8.0)

The tool preparation and quick-fix cell focuses on repairing minor discrepancies, engaging in preventive maintenance and preparing the tool for positioning in the queue for lay up in the laminating cell or moving it to tool storage for use at some later date. Cured part removal from the tool is performed by this activity. They are also responsible for maintaining the vacuum fittings and thermocouple wires used in the curing cell. This cell validates the tool as to tolerance checks, leak checks, and surface preparation. It interfaces with all cells in the center that have an impact on tooling. Figure 3-56 identifies the major configuration items within the tool preparation and quick-fix cell.

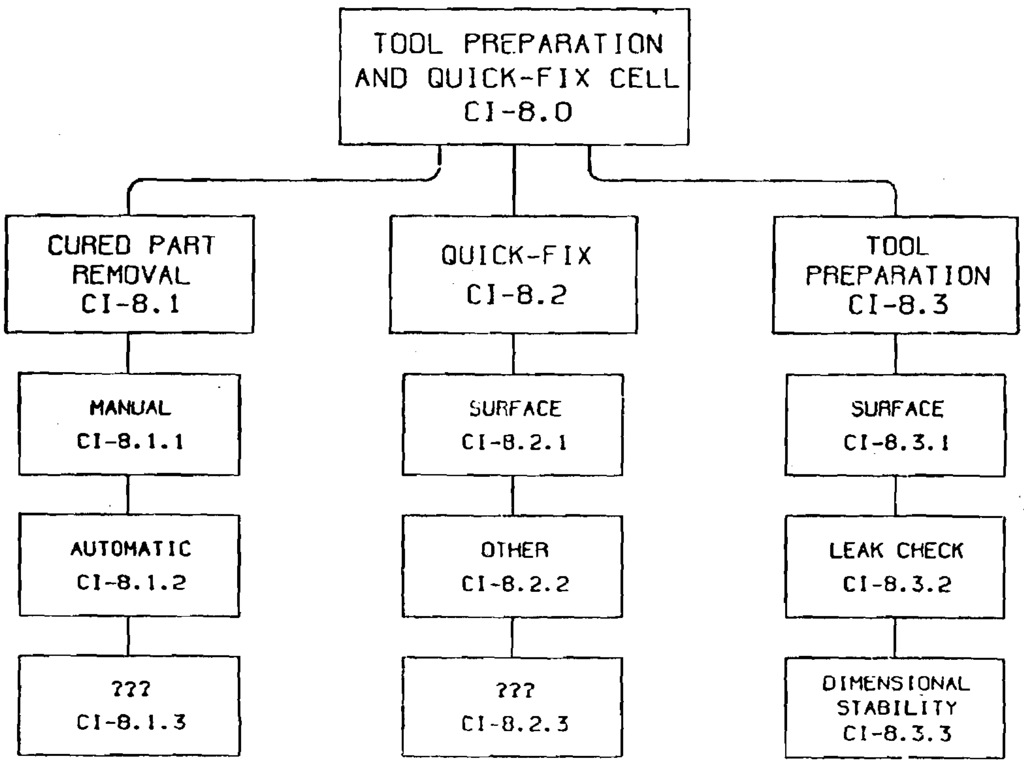


Figure 3-56 Tool Preparation and Quick-Fix Cell

Material Handling System (Configuration Item 9.0)

The material handling system is responsible for moving composite material from the loading dock into the refrigeration units in the laminating cell. This system also inventories and retrieves all consumables associated with the production of composite structures. It is concerned with the total center and not with individual cell handling systems and interacts with the satellite-material systems of each cell. Figure 3-57 identifies the major configuration items within the material handling system.

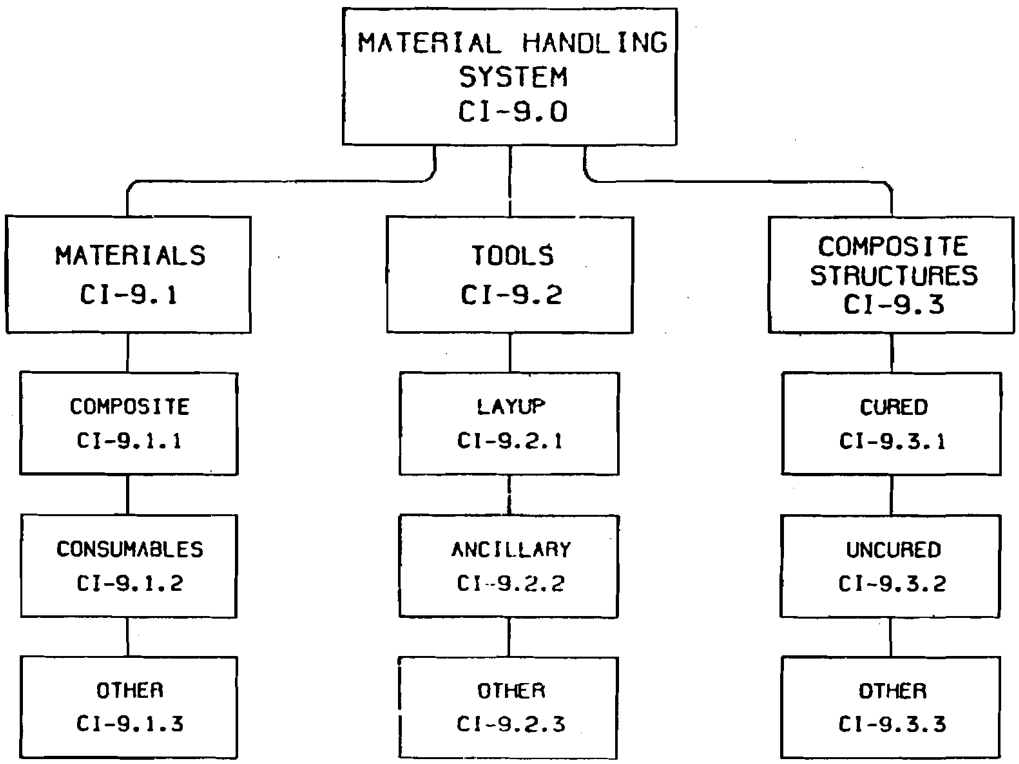


Figure 3-57 Specification Tree - Material Handling System

Design Composite Structure (Configuration Item 10.0)

The design composite structure cell will use automated design tools to design the layup tools used in the ICC, particularly the laminating cell. The major considerations in the design and fabrication of tooling for composite parts are targeted at control of fiber orientation; the contour and size of the part; the location of the part in the assembly; and maintenance of dimensional tolerance control. Some design tools for the design/manufacturing/quality assurance interface are:

- Computer-aided design
- Computer graphics
- The linkage of CAD/CAM
- Computer-aided lofling
- The tie-in with CAD to programs similar to NASTRAN

Figure 3-58 identifies the major configuration items within the design composite structure. Figure 3-59 illustrates the complex engineering/manufacturing/quality assurance interface network.

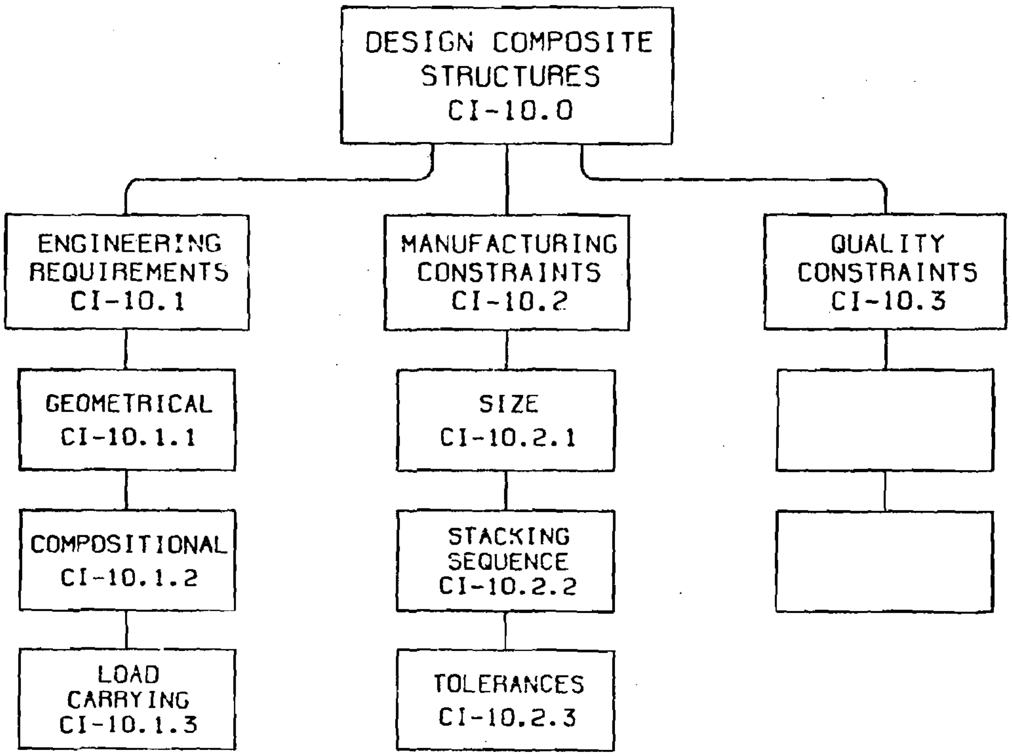


Figure 3-58 Specification Tree - Design Composite Structures

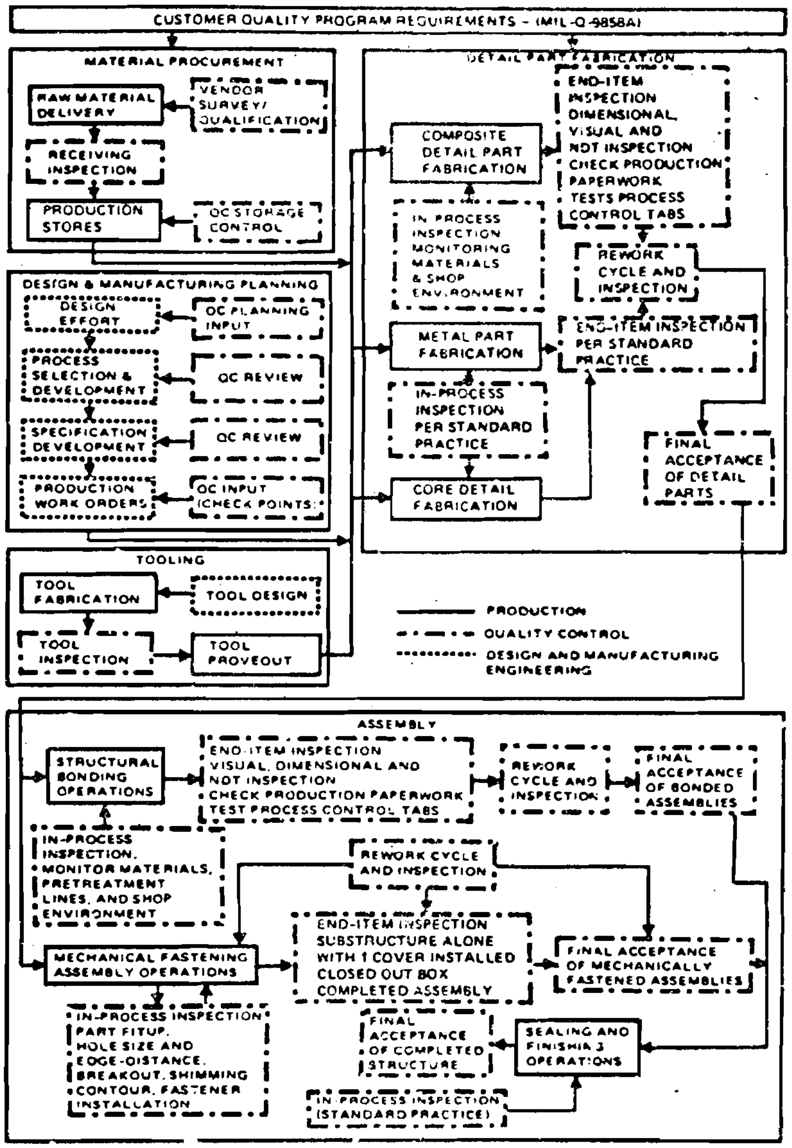


Figure 3-59 Engineering/Manufacturing/Quality Assurance Interface Network

Composites Management System (Configuration Item 11.0)

The composites management system is the mechanism where the production requirements and the resources controlled by the ICC are effectively joined. This system also provides a "look ahead" capability to avoid or minimize potentially costly imbalances between production requirements and available resources. The system provides computer-based support to the following functions:

- o Planning
- o Scheduling
- o Controlling
- o Communicating
- o Quality assurance
- o Performance measurement
- o decision-making support
- o Maintenance of operations
- o Performance improvement
- o Providing feedback information to system external to the ICC.

Figure 3-59 identifies the major high-level configuration items within the composites management system. Figure 3-60 shows these same seven configuration items placed within a systems-oriented framework. As the design shows, the system contains a subset of the factory systems.

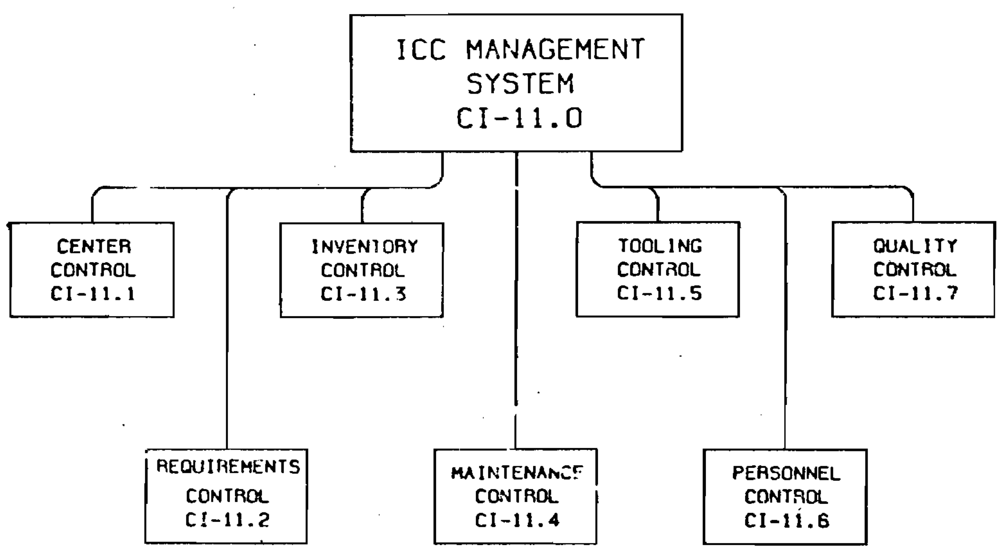


Figure 3-60 Specification Tree - ICC Management System

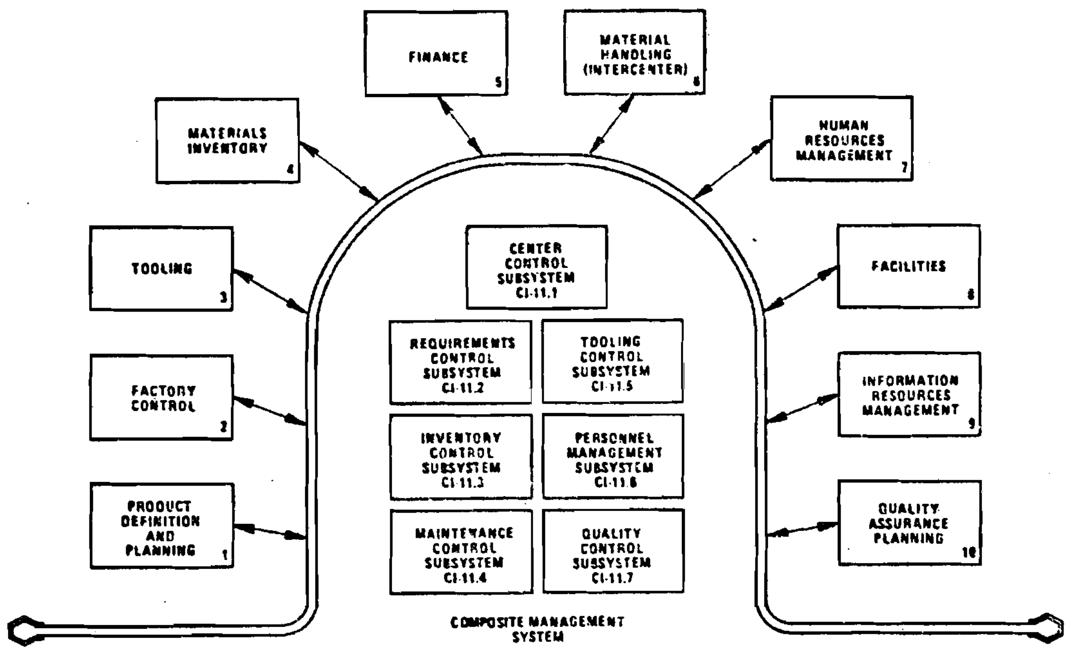


Figure 3-61 Composite Management System Modules

QUALITY ASSURANCE

Quality Assurance for composite components must include two major elements: (1) assurance that the product design will achieve its many requirements, and (2) assurance that the ICC will closely control the production of all characteristics which affect the end result of the product.

The first element is generally covered by the engineering organization during the design phases of product development using inputs from marketing, manufacturing quality assurance, service organizations, and customer representatives.

The second element converns the function of meeting the specifications/tolerances associated with each characteristic. It becomes obvious that the greater the importance of the characteristic and/or the less ability of the shop to meet the specifications, the greater the need exists to control the characteristic by some other means.

One workable system is to reduce both factors to a numerical scale. Each factor is then rated on a scale from 1 to 10. A high relative importance combined with a low ability to meet specifications results in a high need for control and the converse situation would indicate a low need for control.

Marketing, product service, design engineering, manufacturing engineering, quality assurance and shop personnel working jointly can suggest various methods to assure control when the need for control is high and also arrive at a cost-effective and quality-effective solution.

As a last resort, additional or continued inspection and test procedures may be called for until adequate process controlsd can be put in place.

DEVELOPMENT SPECIFICATION APPENDICES

As part of the Task E, Produce Configuration task, the coalition developed a separate volume of Appendices which contains specific Development Specifications for Northrop's, Vought's and General Dynamics' Integrated Composites Center. In addition, this volume also contains an Appendix D, which was General Electric's input on "Plan and Control Composites and Its Relationship to Control Centers."

These appendices, specific to Northrop, Vought and General Dynamics, establish ICC Systems Design Parameters, Configuration Items, Alternative Design Concepts, Subsystem Development Specifications and Quality Assurance.

General Electrics portion envisions composites as a complete "factory" accepting "orders" (in the form of a schedule) for composite assemblies. Their approach facilitates the planning and control of composites assemblies.

These four Appendices (A, B, C and D) were submitted as part of the DS110511000 document which was submitted to the Air Force for approval on 30 June 1983.

3.4 Quality Assurance/Quality Control/Technical Requirements/Tasks (Task D.)

The assurance of Quality cuts across the entire life cycle of an aerospace product - from initial concept, through design, pre-production, production and use. To provide this assurance, a quality plan must be produced to ensure that the quality requirements will be met throughout the product life cycle. Since the quality of the design has a significant impact on the quality of the product, Engineering and Quality must interact closely during the design phase.

Similarly, Manufacturing, Design and Quality must interact during the pre-production phase. During the production phase, the quality plan is used to ensure that the raw materials, components, and subassemblies are being transformed into acceptable parts. Finally, Quality must monitor field performance during the "use and maintain" phase of the life cycle. This data (as well as other Quality Information) is used to provide feedback to aid in evaluating QA/QC effectiveness, reliability and maintainability.

General Electric Company, as part of the Vought, Northrop, General Dynamics coalition, was responsible for accomplishing Task D. SofTech, Inc. also provided additional support for this task.

Task D had three broad objectives:

- The understanding of today's "AS IS" QA/QC environment
- The transferring of technology
- The developing of a recommended Product Assurance Program Management Standard for the Factory of the Future.

Understanding Today's "AS IS" QA/QC Environment - The objective of this task included establishing an "AS IS" QA/QC architecture suitable for being used as a baseline for the QA/QC requirements of Task B - Factory of the Future and Task C - Integrated Composites Center. It also included devising a method of incorporating the QA/QC architecture into the existing "AS IS" manufacturing technology.

Transfer of Technology - This objective included developing a Quality Assurance Manual which would provide a standard approach for modeling, analyzing and improving the "AS IS" QA/QC functions in industry as well as providing a technology transferring medium.

Developing a Recommended Product Assurance Program Management Standard for the Factory of the Future - This task included analyzing MIL-Q-9858A and related standards/specifications for potential deficiencies in the automated environment of the Factory of the Future. The recommended Product Assurance Program Standard recognizes integrated automated management and production systems applicable to the current and future manufacturing environments. This approach is intended to help pave the way toward a paperless manufacturing environment from an integrated quality assurance viewpoint.

These tasks were organized around developing structured graphical models representative of QA/QC functions performed in the aerospace industry which could be used as a baseline understanding for launching other industrial quality technology projects.

The Task D objectives by work breakdown structure is shown in Figure 3-62.

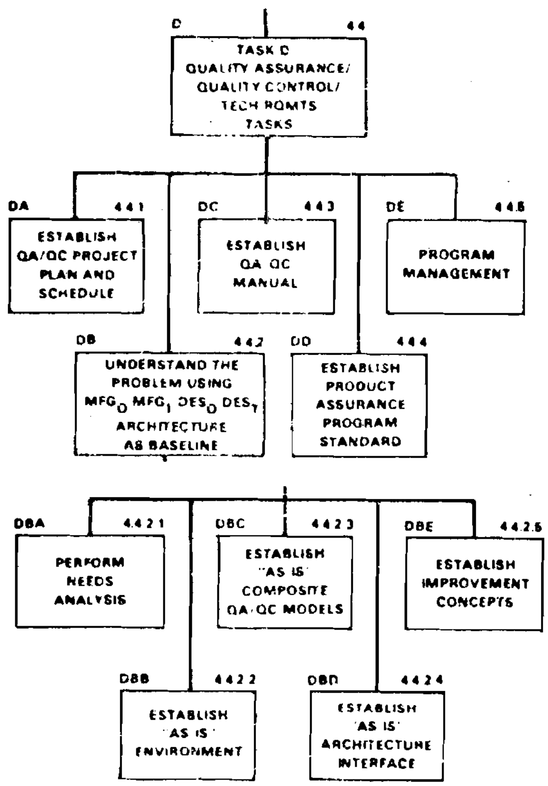


Figure 3-62 Task D Objectives by WBS

3.4.1 Establish QA/QC Project Plan and Schedule (WBS 4.4.1)

The QA/QC Project Plan and Schedule were established in the Project Master Plan and Schedule (PMP110510000) dated 1 January 1982, the schedule revision (PMP110510000A) dated 1 February 1982 and in the 15 February 1983 revision (PMP110510000B). As part of the Schedule, subtasks covering Understanding the Problem, Establish a QA/QC Manual and Establish Product Assurance Program Standard were defined and a time schedule for their accomplishment was established as a series of program milestones.

The scope of the "AS IS" QA/QC environment as it related to the "AS IS" Architectures of Manufacturing (MFG0) and Design (DES0) was developed in conjunction with the Project Master Plan and schedule. A "strawman" IDEF0 model (A-0 and A0 diagrams) "Assure Product Quality" was developed and provided the basis for future coalition efforts in modeling their company specific QA/QC functions. The A-0 diagram is illustrated in Figure 3-63 and the A0 diagram is illustrated in Figure 3-64. As shown in Figure 3-64, the major activities of the QA/QC function are:

A1 Develop Quality Requirements
A2 Prepare Quality Plan
A3 Provide QA/QC Resources
A4 Perform Quality Control
A5 Evaluate QA/QC Effectiveness

3.4.2 Understand The Problem Using The MFG0, MFG1, DES0 and DES1 Architecture (WBS 4.4.2)

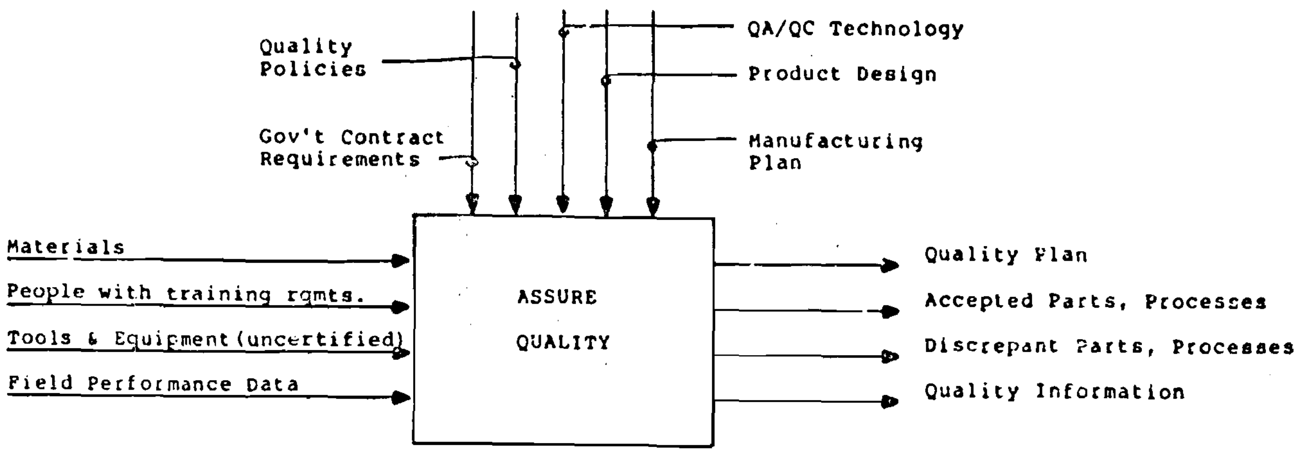
QA/QC activities that are associated with the life cycle of an aerospace product, begin with the conceptual studies performed prior to responding to a proposal and go through to the analysis of field data. In undertaking this task, emphasis was placed on both the technical and management issues of the QA/QC function. IDEF0 and IDEF1 modeling techniques were used to assist in understanding the "AS IS" QA/QC function and its relationship to MFG0, MFG1, DES0 and DES1.

Four specific documents were developed from the results of this WBS item. These documents are:

- Scoping Document which defined the contractual effort and QA/QC relationship to existing ICAM Architectures

- System Environment Document which investigated various manufacturing "AS IS" QA/QC systems, developed integrated site specifice and generic IDEF models and established architecture interfaces with MFG0 and DES0. The architecture interfaces have been published in AFWAL-TR-82-4063, Volume V, Architecture Part III, Composite Function Model of "Manufacturing Product" (MFG0).

- Needs Analysis Document - which investigated various manufacturing "AS IS" QA/QC systems and defined the specific needs of those systems

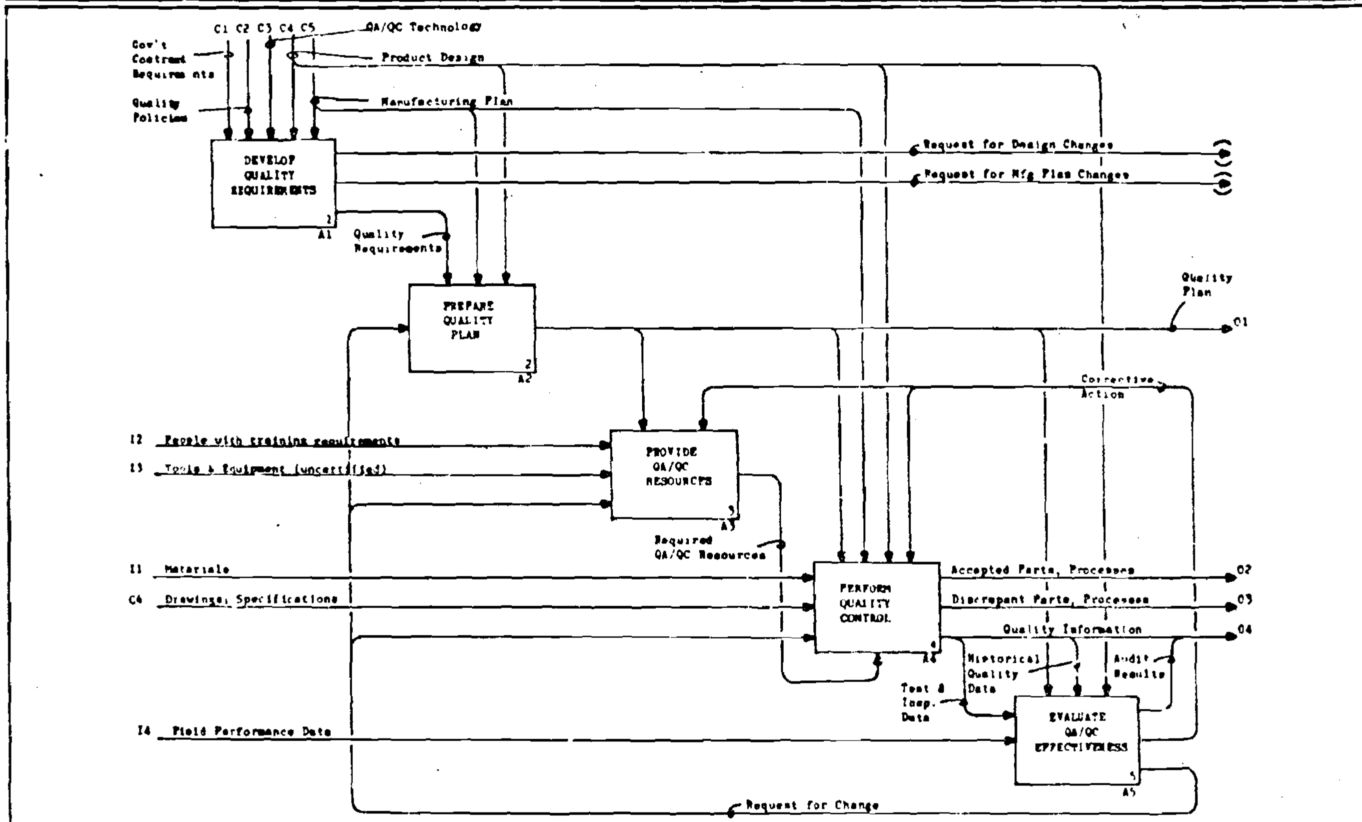


<u>Viewpoint:</u> From the perspective of the QA/QC project manager

<u>Purpose:</u> To describe the activities and interfaces within "AS-IS" QA/QC in Manufacturing and Design and provide guidance for development of models from coalition members.

Figure 3-63 Baseline Assure Quality Model

USED AT:	AUTHOR: R. WETTACH/B. SHEPHERD PROJECT: ICAM 1105 NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: 1/25/82 REV: 1	WORKING DRAFT RECOMMENDED XX PUBLICATION	READER DATE	CONTEXT:



NODE: QA/A0	TITLE: ASSURE QUALITY	NUMBER RW/BS-6

Figure 3-64 A0 Diagram - Assure Quality

- o System Requirements Document - which translated "needs" into system requirements and identified improvement concepts.

Figure 3-65 illustrates the various documents which were produced as a result of the Task D effort. The following paragraphs provide a summary of the activities that contributed to these documents.

3.4.2.1 Perform Needs Analyses

The Needs Analysis activity addressed the "AS IS" environment in terms of cost/performance drivers and human factors affecting the current system and identified where improvements should be made. The six major activities of the QA/QC system were identified as:

- o Prepare for future QA/QC aerospace demands
- o Develop QA/QC RFP response
- o Prepare QA/QC quality plan
- o Implement QA/QC program plan
- o Perform to QA/QC program plan
- o Evaluate QA/QC effectiveness

Key areas of needs were summarized and structured in a needs analysis matrix (see figure 3-66). Areas of need have been identified and combined in the following categories:

- o Early Integration of Quality Assurance/Control considerations
- o QA/QC Equipment
- o QA/QC Information Handling
- o Technical Skills
- o Software Quality Assurance

Integration of the Assurance of Quality - The following key areas of needs were identified for the Integration of QA/QC activities. These needs affect all functions from Marketing through Engineering, Manufacturing and Logistics Support.

- o Early prevention/detection of quality problems and capitalizing on quality opportunities

- o New QA/QC technology compatible with future design concepts and factory of the future designs and change proposals

- o Utilize present quality problem data in future designs and change proposals

- o Early availability of design and manufacturing requirements for inspection and test planning and equipment requirements

- o Reduce QA/QC resource inefficiencies associated with project organizations.

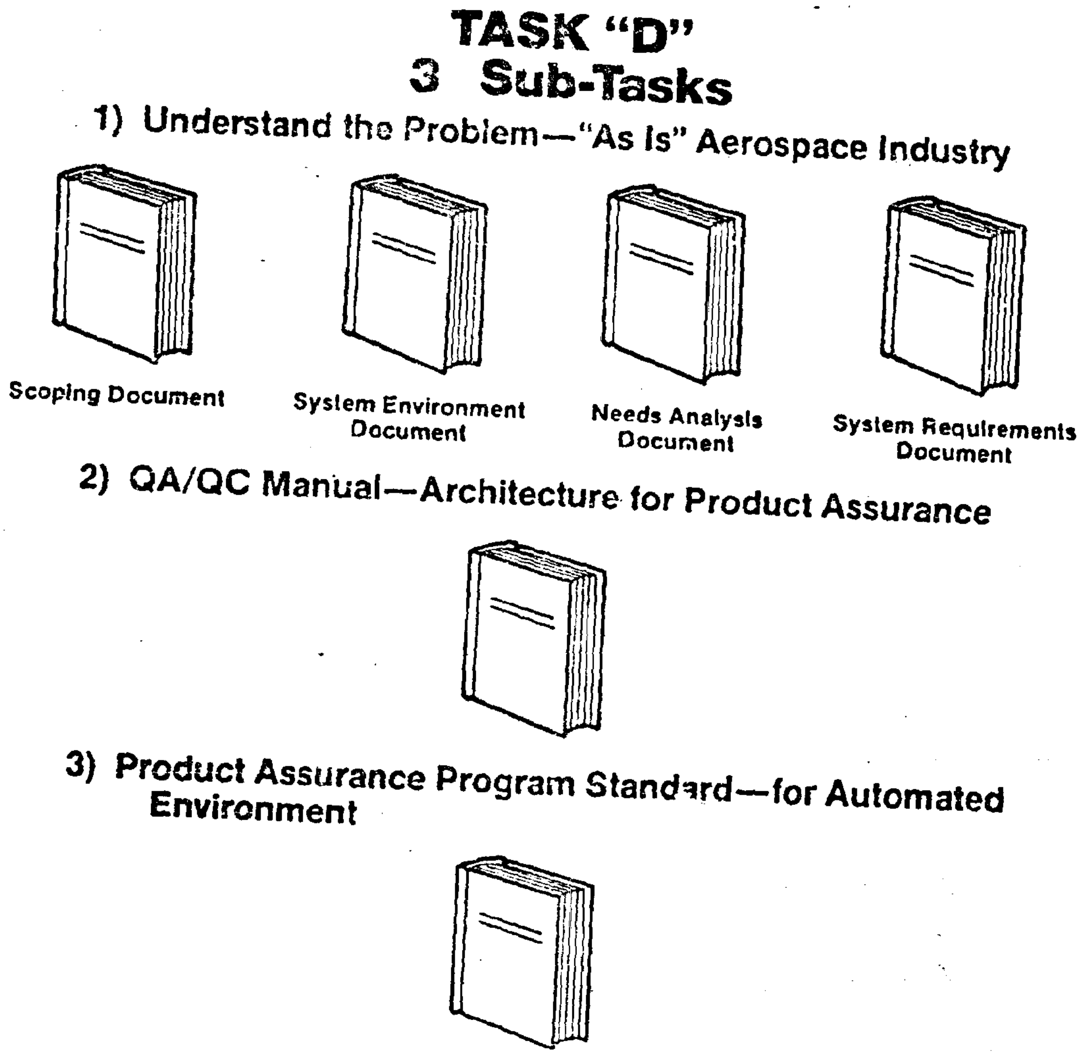


Figure 3-65 Documents Produced on Task D

USED AT	AUTHOR COALITION TEAM PROJECT 1105-TASK D NOTES 1 2 3 4 5 6 7 8 9 10	DATE 4/15/82 REV	WORKING DRAFT RECOMMENDED PUBLICATION	READER DATE	CONTEXT

NODE		AREA OF NEEDS					
Number	Name	Technical Skills	Organization Interface	Information	Tools, Methods, Facilities	Other
A1	1. PREPARE FOR FUTURE QA/QC AEROSPACE DEMANDS		3.3.2.1.1 Early Prevention/ Detection of Quality Problems		3.3.2.1.7 QA/QC Technology Compatible with Future Design [illegible] and [illegible] Manufacturing Innov Etc	
A2	2. DEVELOP QA/QC RFP RESPONSE	3.3.2.1.5 Reduce QA/QC Resource Inefficiencies Associated with Project Organizations		3.3.2.3.4 Submit Quality Plan in Response to RFP using Demonstrated Strengths 3.3.2.3.7 Automate Repetitious QA/QC Data		
A3	3. PREPARE QA/QC PROGRAM PLAN	3.3.2.4.2 Provide Closer Match Between QA/QC Personnel & Position Skill Rqmts	3.3.2.1.4 Early Availability of Design/Manufacturing Rqmts for Inspection and Test Planning			3.3.2.5. Software Quality Assurance Needs
A4	4. IMPLEMENT QA/QC PROGRAM PLAN	3.3.2.4.1 Provide or Reduce Need for QA/QC Skills Where They are in Short Supply		3.3.2.3.5 Programs for NC-type Test 3.3.2.3.6 Current Relevant Inspection Data to Shop Floor	2 Test/Inspection of 2 1 Composite Integrity 2 2 Composite Dimensions 2 3 Machined Parts 2 4 Wire Harness 2 5 Sheet Metal 2 6 Electronic Circuit	3.3.2.5 Software Quality Assurance Needs
A5	5. PERFORM TO QA/QC PROGRAM PLAN		3.3.2.1.3 Utilize Present Quality Problem Data in Future Designs and Change Proposals	3.3.2.3.2 Improve Flow of Shop Floor Inspection Data 3.3.2.3.3 Secure Useful Incoming Inspection Data		3.3.2.5 Software Quality Assurance Needs
A6	6. EVALUATE QA/QC EFFECTIVENESS	3.3.2.4.3 Provide QA Audit Measuring the Adequacy of System to Assure Product Quality		3.3.2.3.1 Provide QA/QC Field Information for Early Problem Identification and Solution		3.3.2.5 Software Quality Assurance Needs

NODE	TITLE	NUMBER
QA/AO	Completed QA/AO Structured Needs Matrix	

Figure 3-66 Completed QA/AO Structured Needs Matrix

<u>QA/QC Equipment Needs</u> - As highly automated production systems are integrated into manufacturing design, the tendency has been to overload the Quality Assurance requirements in the overall design. As a result, the traditional methods of inspection seriously impact production. Inspection productivity can be increased by automating labor intensive inspection processes. There must be interactive inspection and verification aimed at non-conformance prevention and timely and effective preventive maintenance. Some key needs in this area are:

- o Inspections of Internal Integrity of Composites
- o Composites Dimensional Inspections
- o Detailed Machined Part Dimensional Inspection
- o Electrical Wire Harness Inspection
- o Sheet Metal Blanking Inspection
- o Automated/In-line Electronic Circuit QA/QC Inspection

<u>QA/QC Information Handling Needs</u>

Due to the labor intensive nature of inspection data collection in the Factory of Today, a large part of an inspector's time is spent in filling out forms. Information must be inputted manually. Selected portions of the information are archived and storage and retrieval is usually totally manual. Information in the form of blueprints, specification and procedures is usually distributed manually. Thus, there exists a need to eliminate much of the manual interaction now required. Automated information management systems that can handle the collection, analysis and reporting of inspection data are required. The coalition team identified seven key areas of need associated with QA/QC information handling. They were:

- o Provide QA/QC field information for early problem identification and solution

- o Improve the collection, processing, storage and retrieval of shop floor inspection data

- o Secure useful incoming inspection data in a timely manner

- o Submit a quality plan in response to the RFP that utilizes demonstrated strengths

- o Ensure correct inspection programs are loaded on numerical control-type inspection equipment when part arrives

- o Provide only current relevant inspection data to the shop floor

- o Reduce the time and cost to incorporate repetitious QA/QC.

<u>Technical Skills Needs</u>

There were three major areas of needs associated with QA/QC skills identified by the coalition team. These were:

- o Obtain and maintain technical skills in high demand and short supply
- o Make effective use of available QA/QC skills
- o Allocate the range of skills required to effectively perform certain QA/QC tasks.

These needs are not unique to the aerospace industry. They are associated with staffing and management functions of all organizations. However, there are possible technical solutions which may alleviate these needs. They are:

- o Provide or reduce the need for QA/QC skills where they are in short supply
- o Provide a closer match between QA/QC personnel and position skill requirements
- o Provide a quality assurance audit capability to measure the adequacy of the QA/QC systems.

Software Quality Assurance Needs

Software, like hardware, is crucial in terms of cost, schedule and performance and deserves the same level of emphasis as hardware. Software includes operating systems, supervisory systems, compilers, test routines and application programs. Some of the problems which exist in the software area are:

- o Poor requirements definition
- o Inadequate systems engineering
- o Inability to track software development progress
- o Inadequate design change and configuration control
- o Improper matching of test and verification with requirements
- o Availability of support software when needed.

The Needs Analysis document (NAD110513000) published on 24 June 1982 expands on the summation of the needs described in the preceding paragraphs and highlights the background, human factor issues, cost drivers, benefits (if corrected) and the estimated cost benefits in dollars and as a percentage of known costs.

3.4.2.2 Establish "AS-IS" Environment (WBS 4.4.2.2)

The major modeling effort occurred in support of meeting the requirements for a System Environment Document (SED). That document contains the "factory view" models from each of the coalition members as well as the "composite view" IDEF0 (functional) and IDEF1 (informational) models. The final composite IDEF0 model had 143 nodes ranging from "Develop New Technologies" to "Perform NDT Inspection."

Three aircraft contractors (Northrop, Vought and General Dynamics) collected data to develop three separate models of "AS IS" factory QA/QC views. These views were representative of multipurpose production centers (i.e., assembly, machining, electronics, composites and fabrication). The viewpoint was from members of the Task D coalition project team. Data was collected from those who had the most information in whatever activity was being modeled. This data, then, became the baseline for the individual factory view models. The assignments for these view models were as follows:

- General Dynamics would model upper level management and expand into Test/Inspect and evaluate for the electronics area

- Northrop would do the same for the composites area

- Vought would do likewise for the sheet metal, machined parts and assembly areas.

Figure 3-67 is a factory view of General Dynamics' IDEF0 Function Model. Figure 3-68 is a factory view of Northrop's generic QA/QC functions which occur throughout the entire life cycle of an aerospace product. Figures 3-69, 3-70 and 3-71 show the detailed architecture and the subtasks involved in Northrop's QA/QC functions involved with the chemical and physical testing of prepreg in the composite area. Figure 3-72 is Vought's IDEF0 model of its generic QA/QC functions which occur across the life cycle of an aerospace product. Figure 3-73 is an in-depth model of sheet metal and extruded parts QA/QC inspection. Figure 3-74 is a similar example for sheet metal and extrusion inspection and Figure 3-75 demonstrates a model of assembly test, inspection and assembly procedures.

A detailed discussion and description of the "AS IS" models is presented in the Task D, System Environment Document (SED10513000) of 31 August 1982.

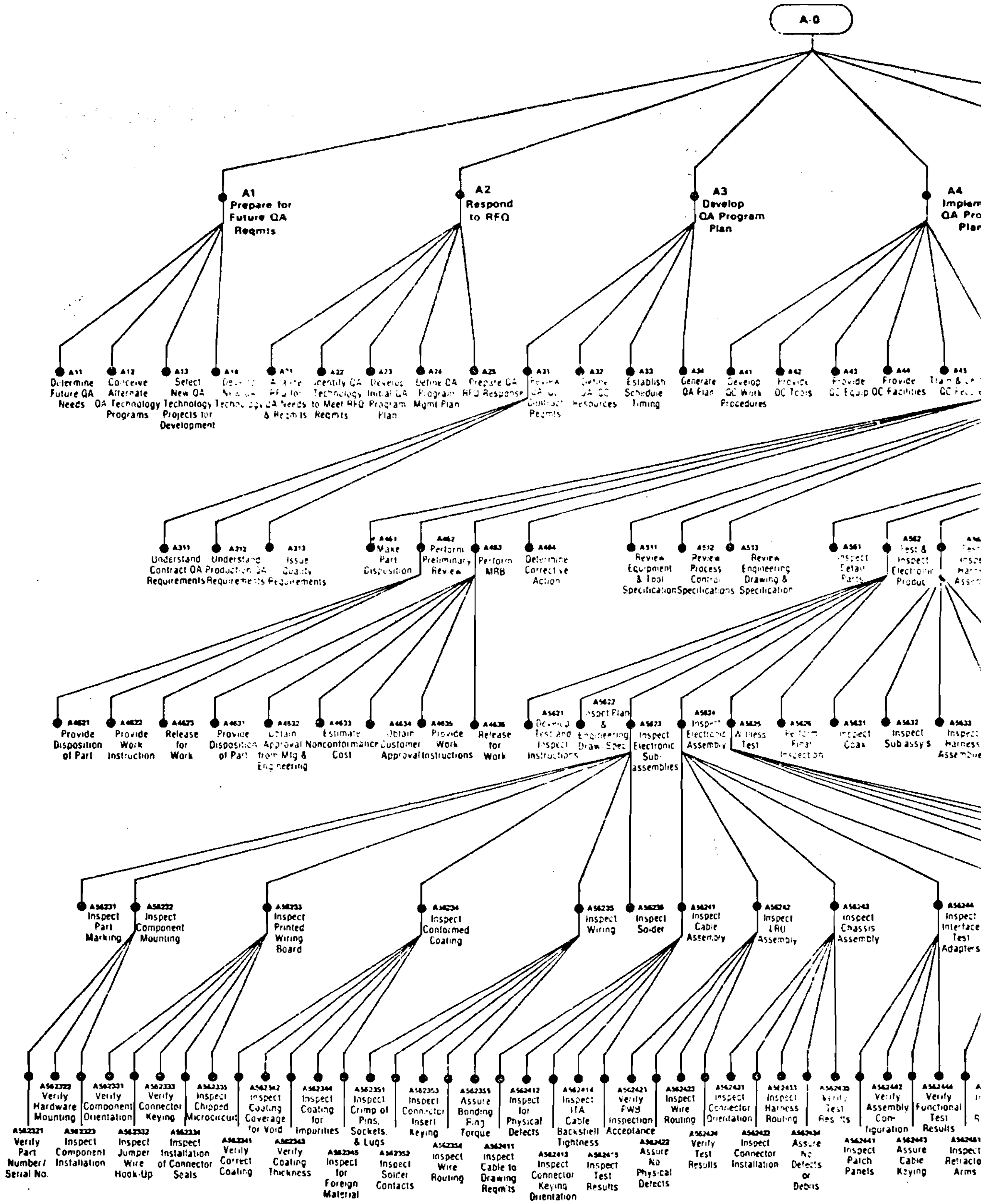
3.4.2.3 Establish The "AS-IS Composite QA/QC Models (WBS 4.4.2.3)

The Northrop, Vought and General Dynamics Factory View models were used to develop the IDEF0 Composite View models. The IDEF1 Composite view model was reviewed by SofTech and approximately 75% of the SofTech suggestions were incorporated into the final model.

Working as a team, the coalition members reviewed and identified the commonalities of the three factory view models from which the composite view, function and information models were developed.

Figure 3-76 is the QA/QC composite model node tree representing the combined efforts of all participants. Figures 3-77 illustrates an Entity Class Function view of the IDEF1 Information Model.

Assure Product Quality



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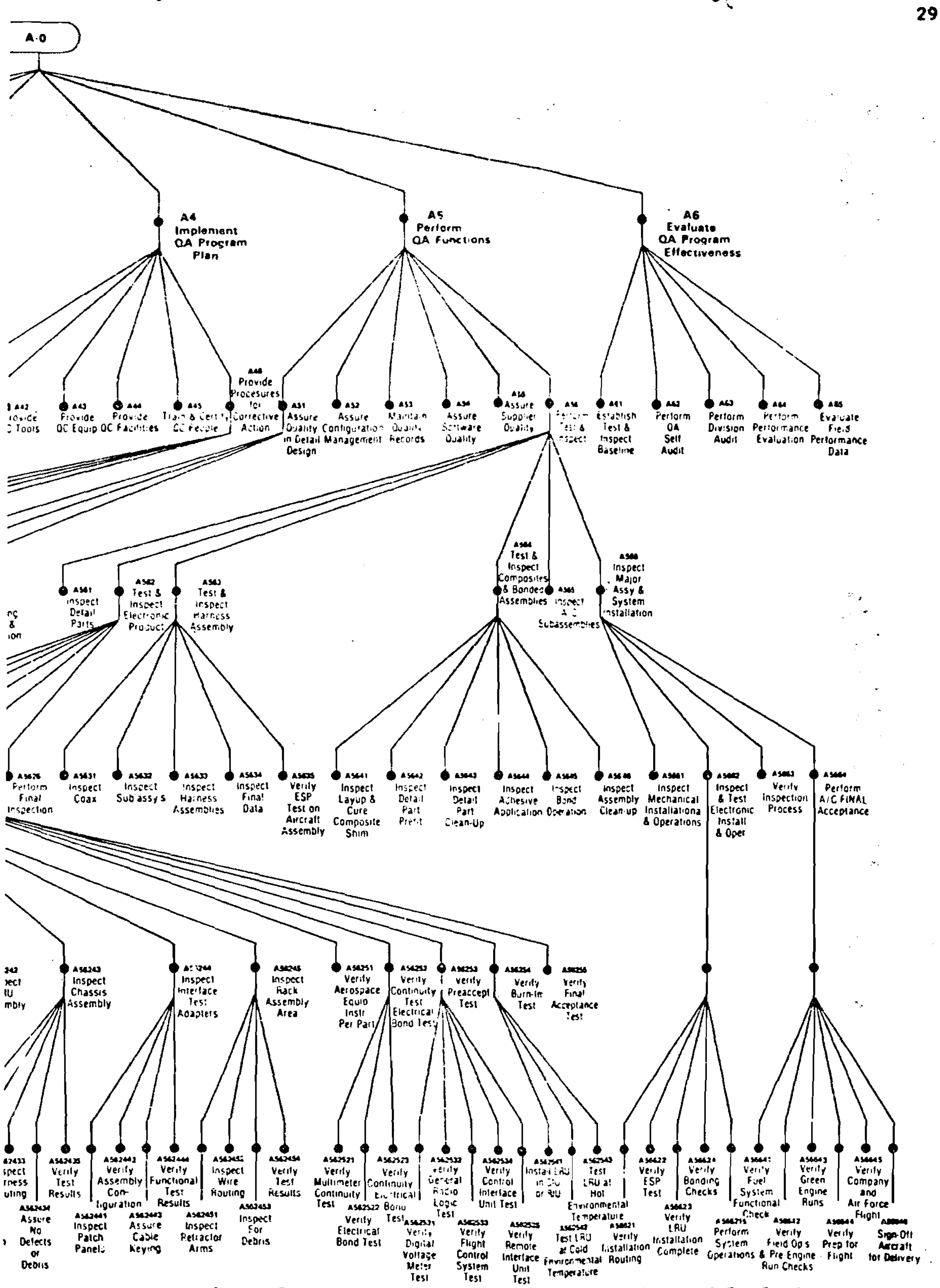


Figure 3-67 General Dynamics IDEF0 Function Model of Electronic Fabrication QA/QC Test and Inspect

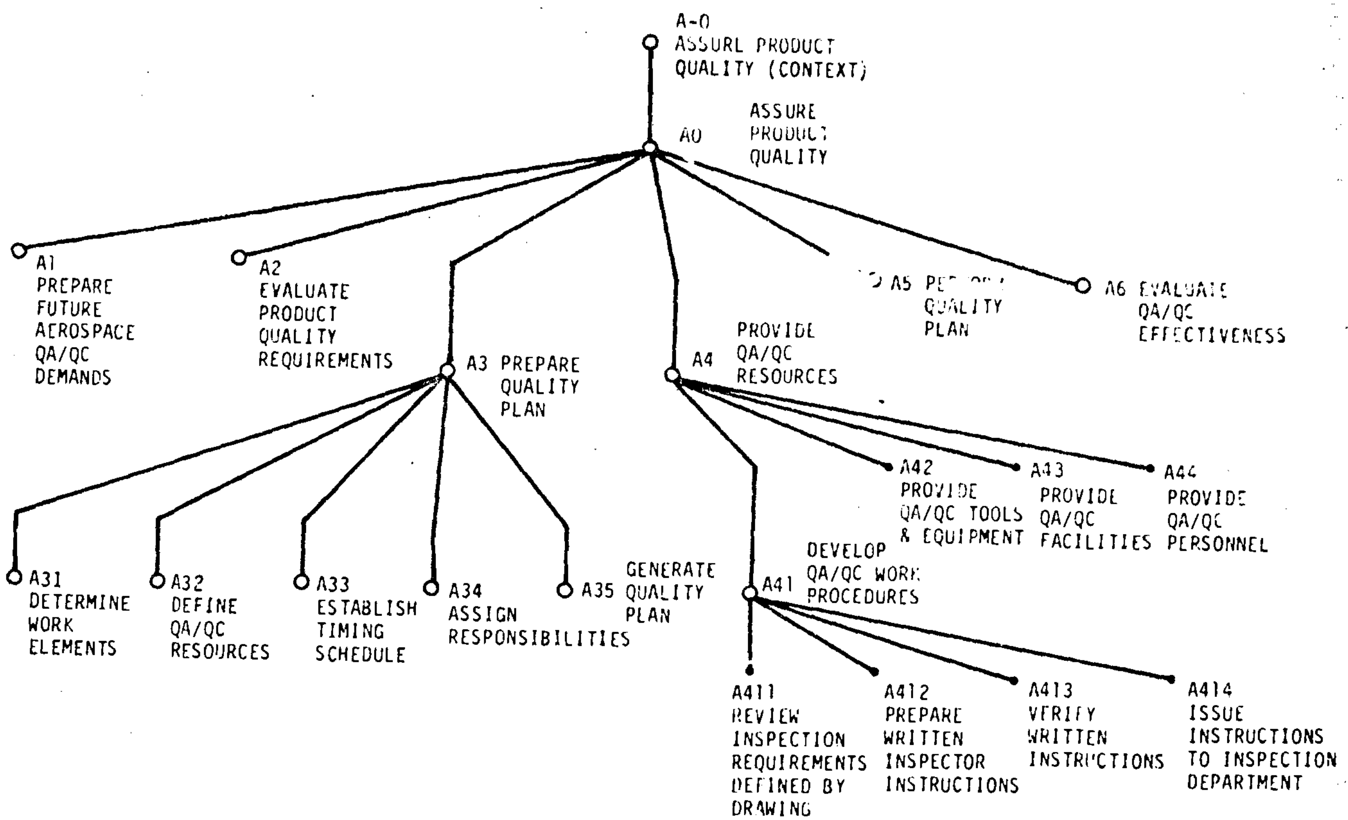


Figure 3-68 Factory View of Northrop's Generic QA/QC Function

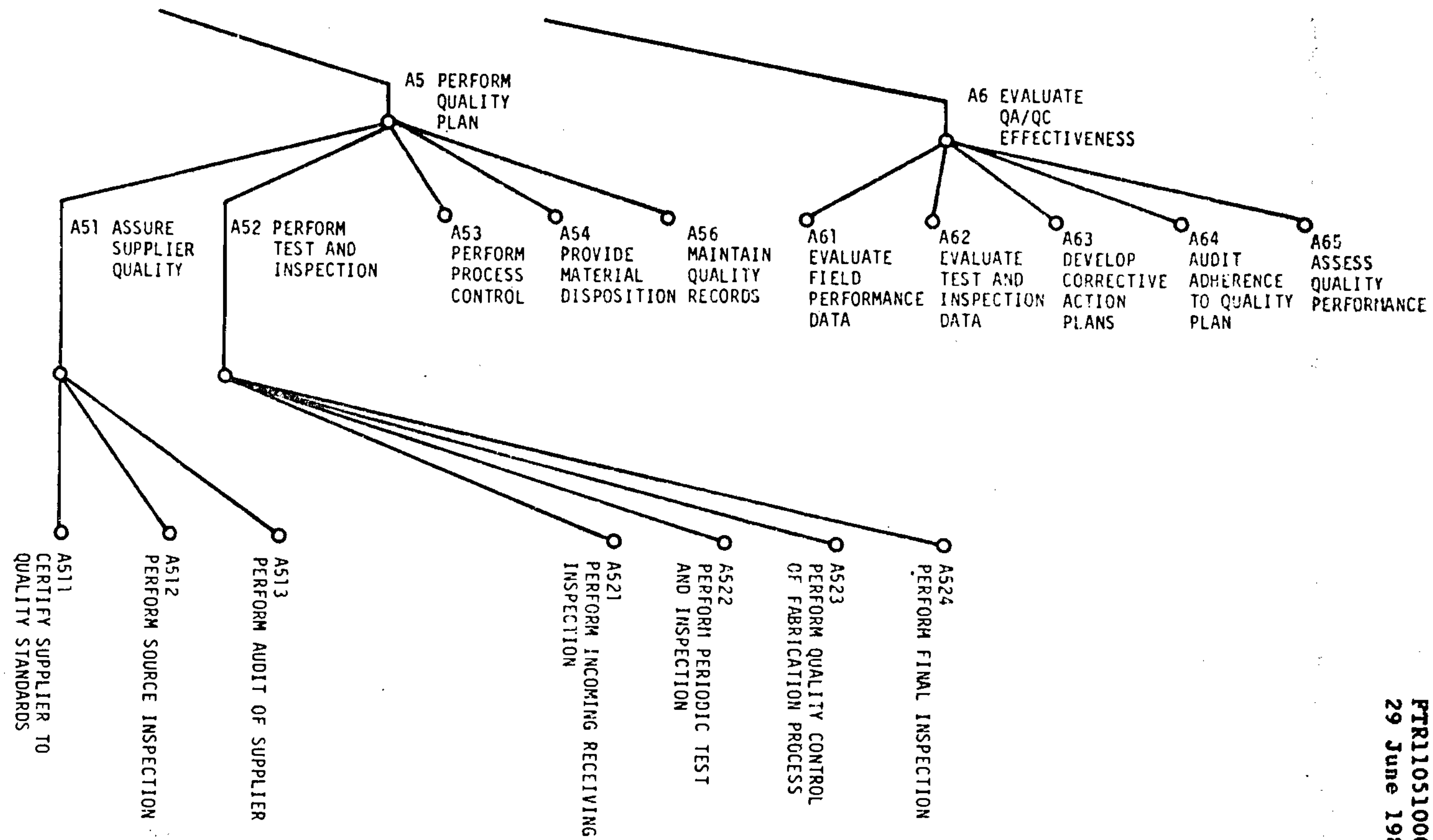


Figure 3-69 Northrop's Architecture of Its QA/QC Functions in the Composite Area

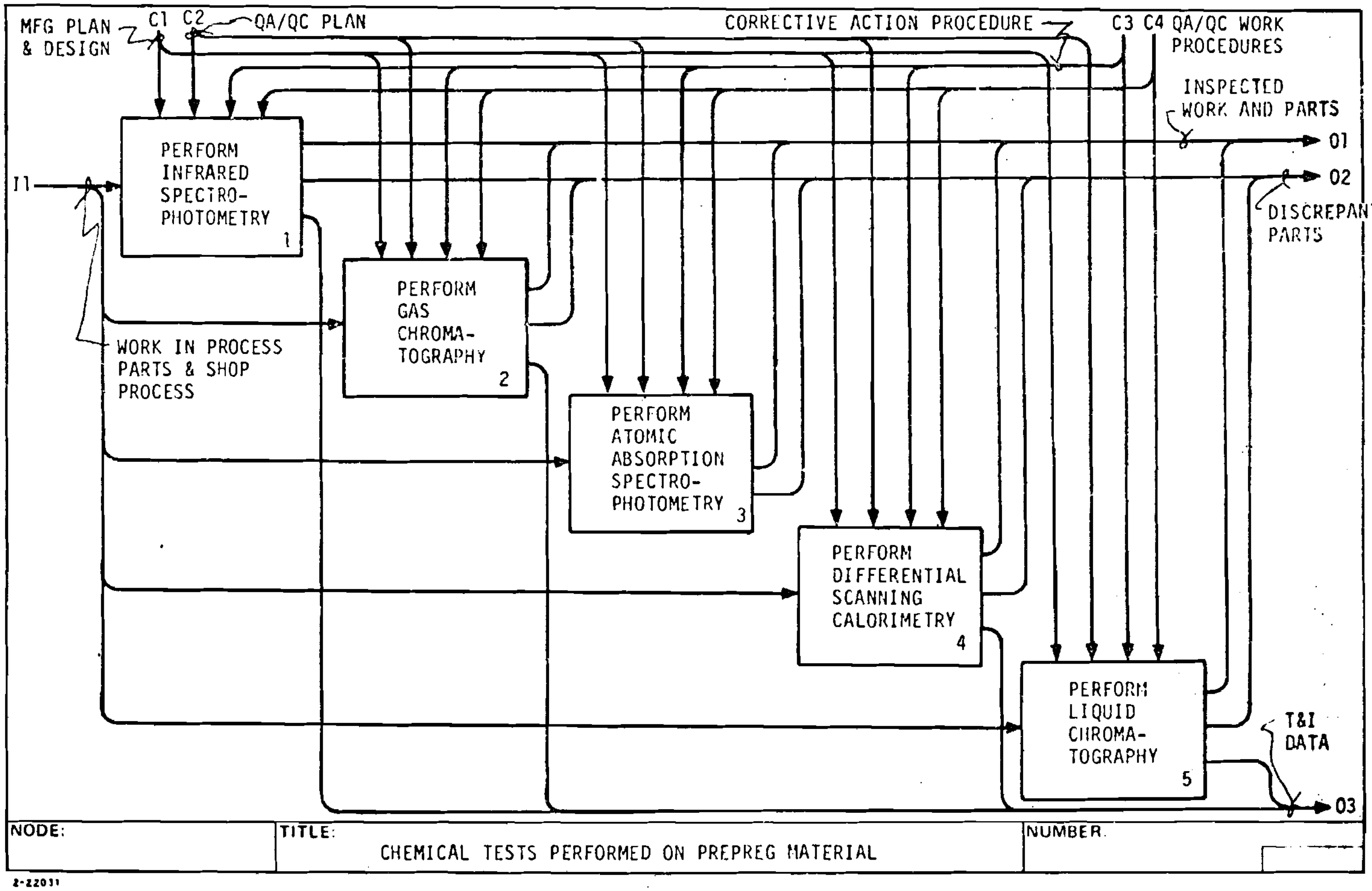


Figure 3-70 Chemical Tests Performed on Prepreg Material

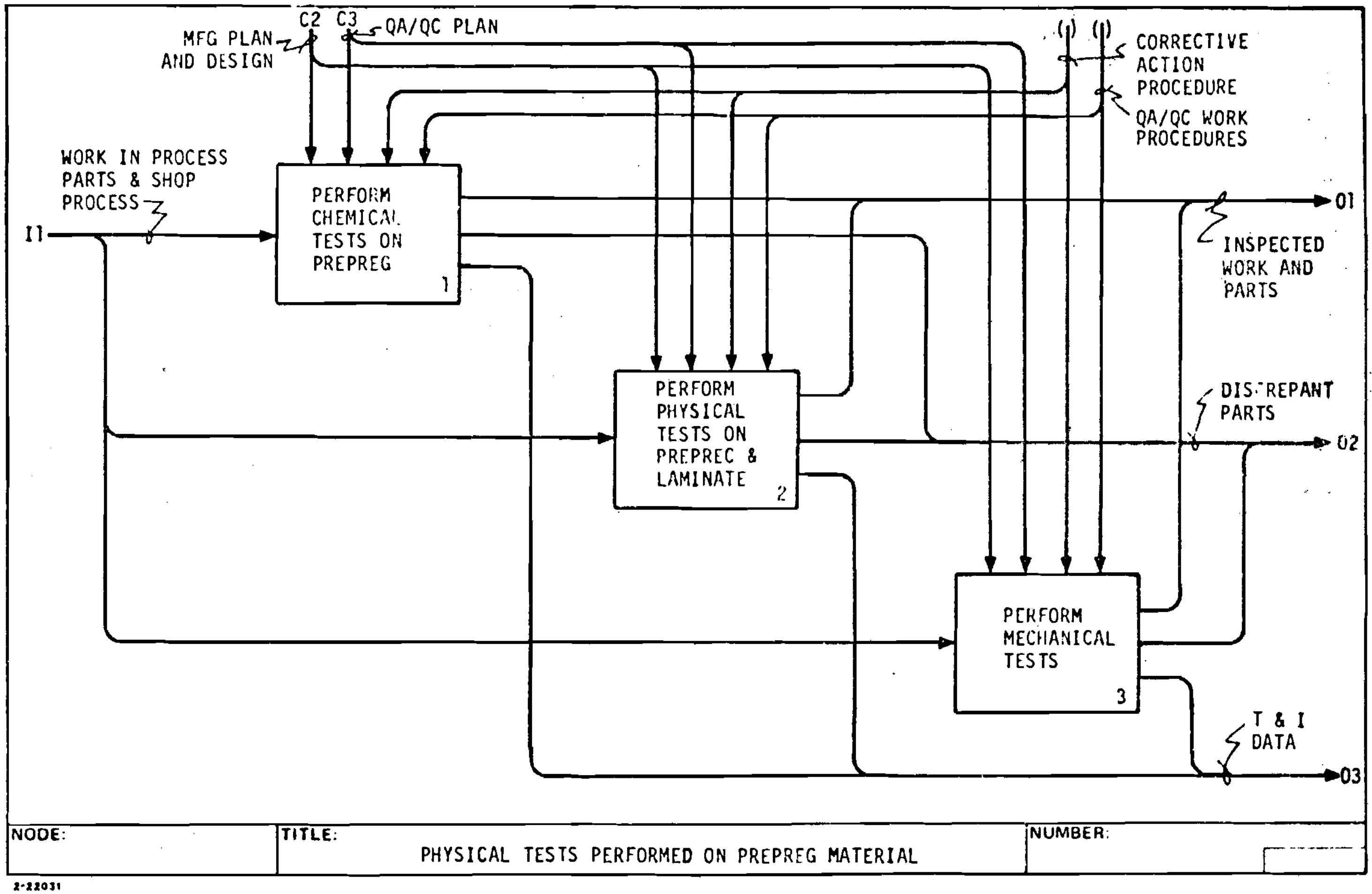


Figure 3-71 Physical Tests Performed on Prepreg Material

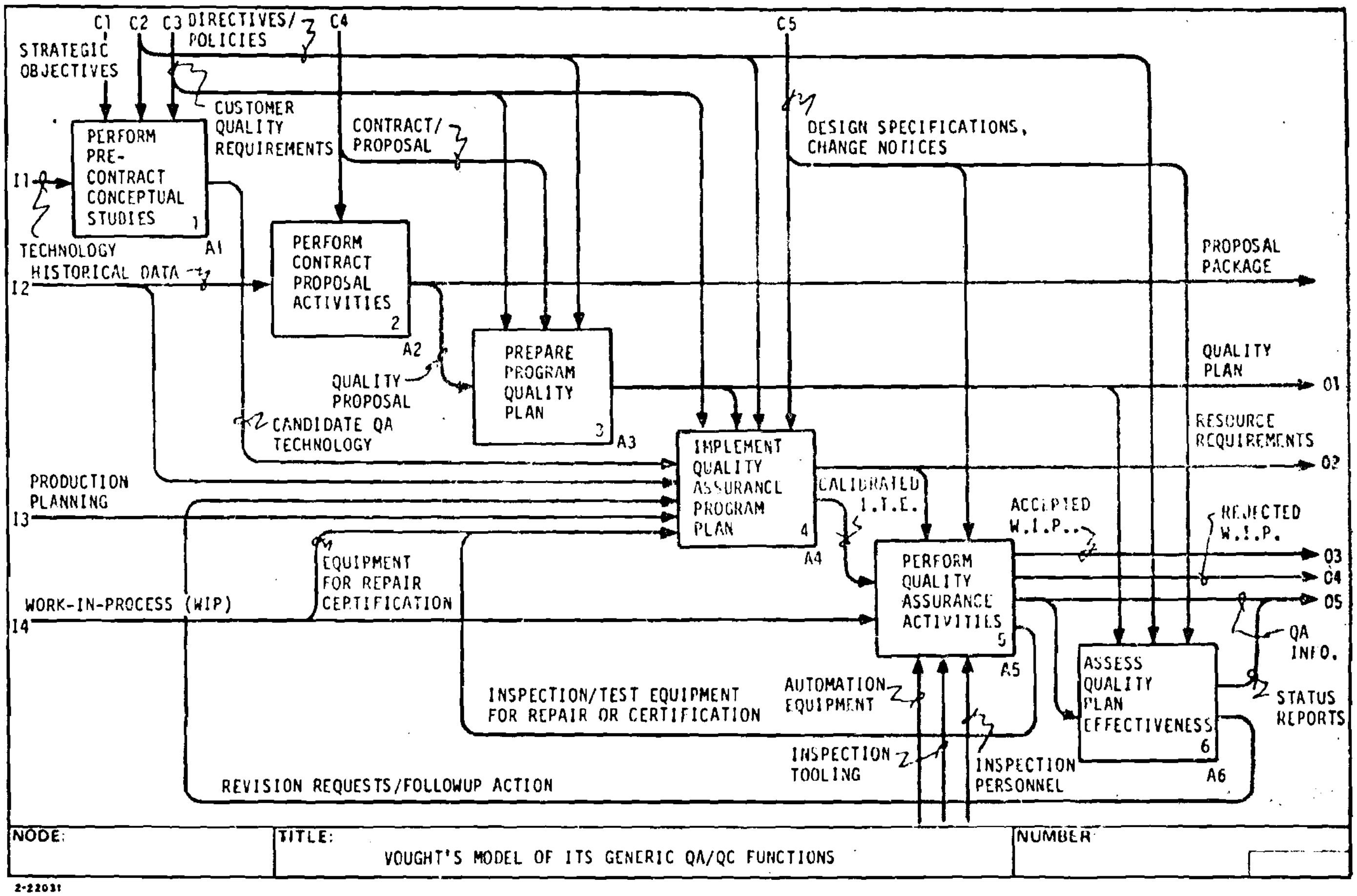


Figure 3-72 Vought's Model of Its Generic QA/QC Functions

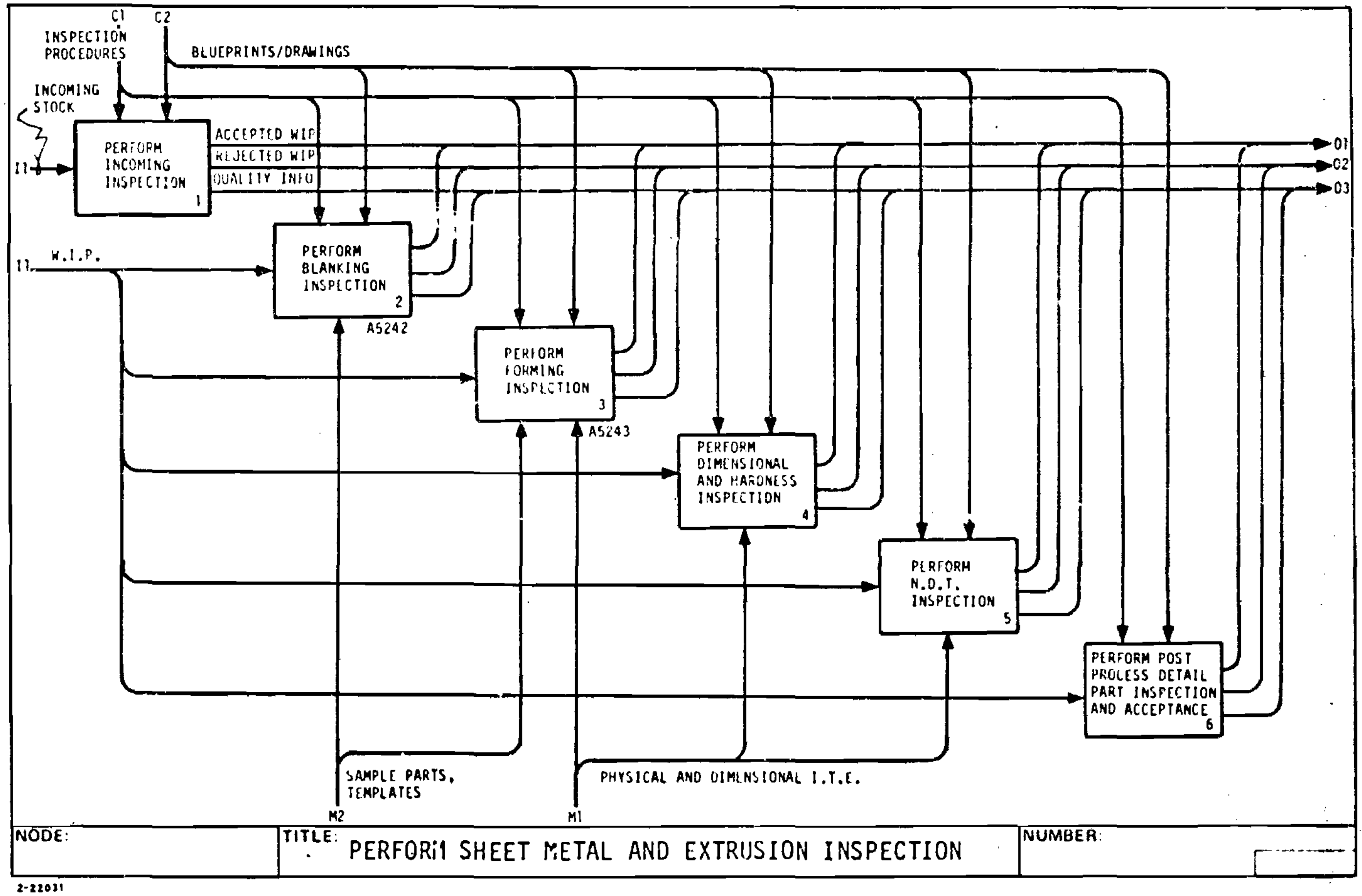


Figure 3-73 Perform Sheet Metal and Extrusion Inspection

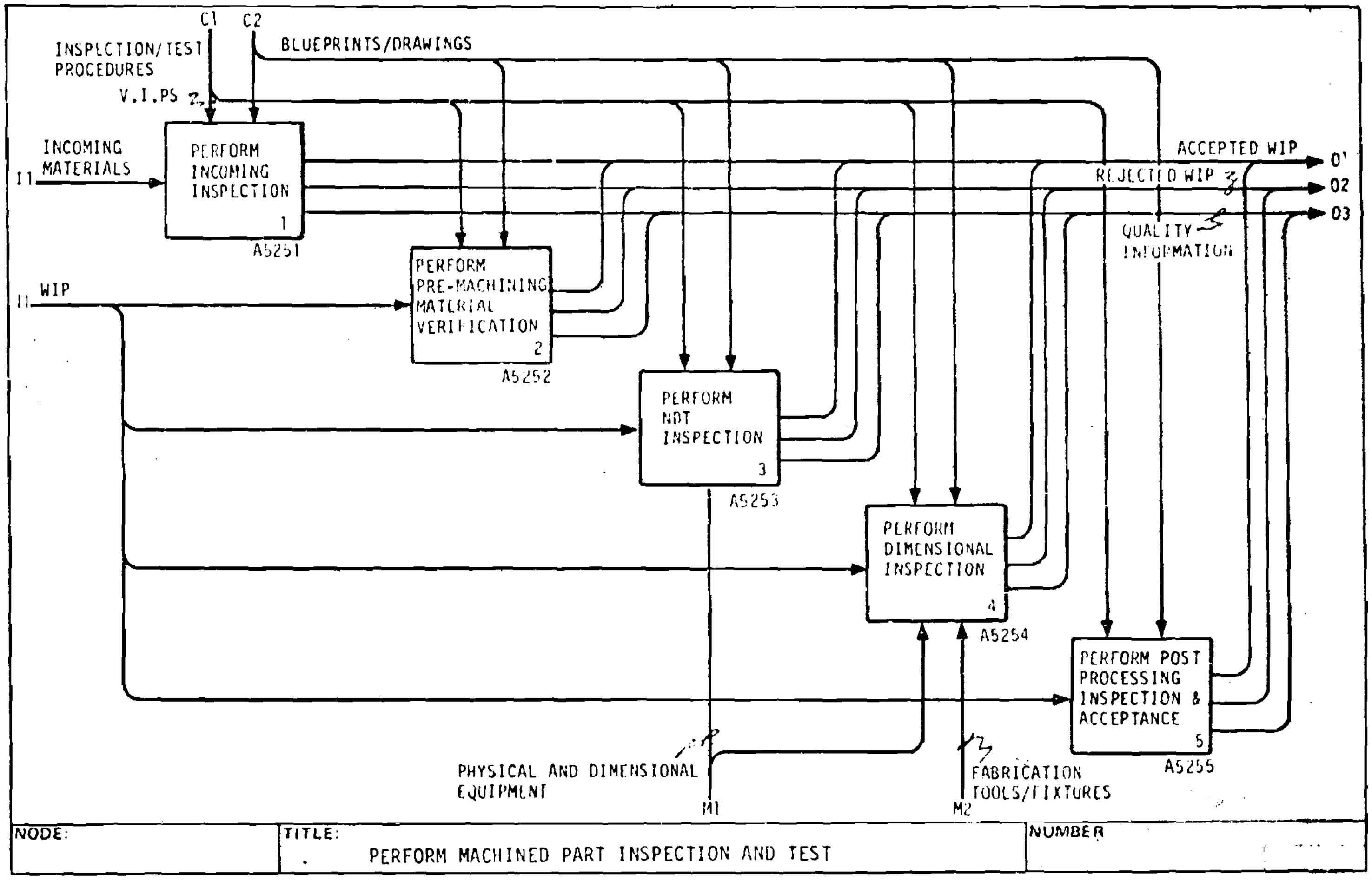


Figure 3-74 Perform Machined Part Inspection and Test

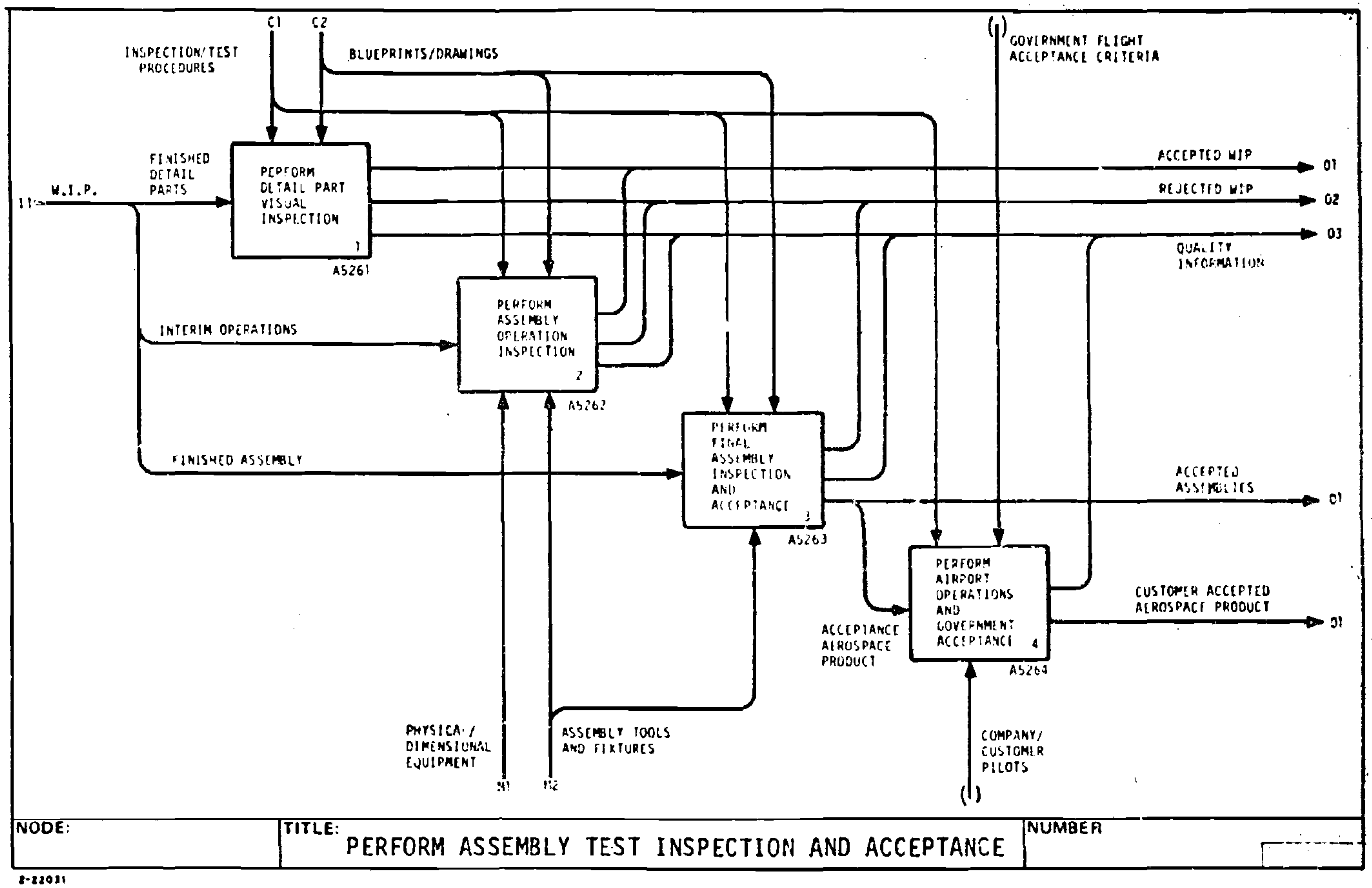


Figure 3-75 Perform Assembly Test Inspection and Acceptance

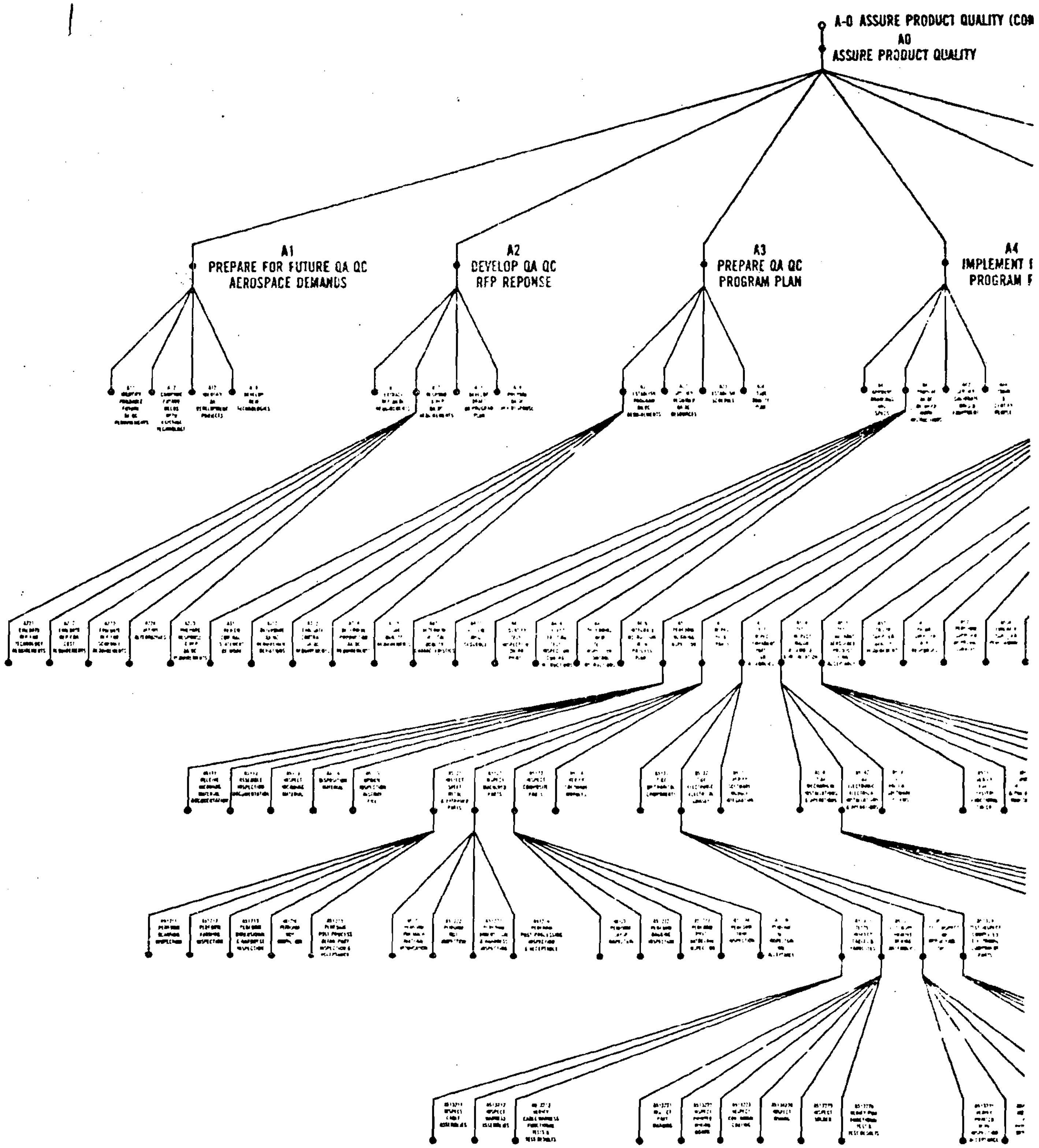
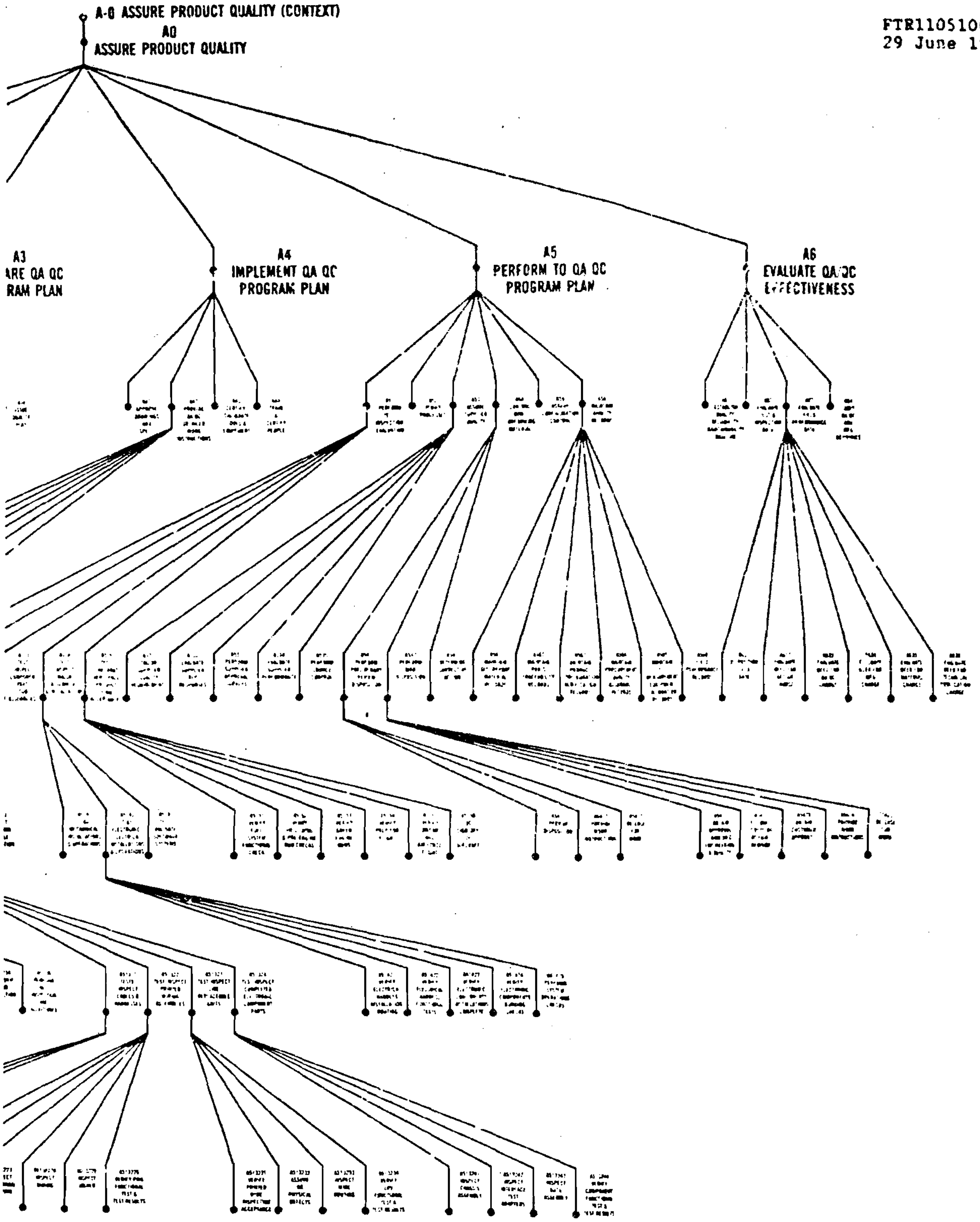


Figure 3-76 QA/QC Composite View Architecture


A-0 ASSURE PRODUCT QUALITY (CONTEXT)
A0
ASSURE PRODUCT QUALITY
A3
ARE QA QC
RAM PLAN
A4
IMPLEMENT QA QC
PROGRAM PLAN
A5
PERFORM TO QA QC
PROGRAM PLAN
A6
EVALUATE QA/QC
EFFECTIVENESS

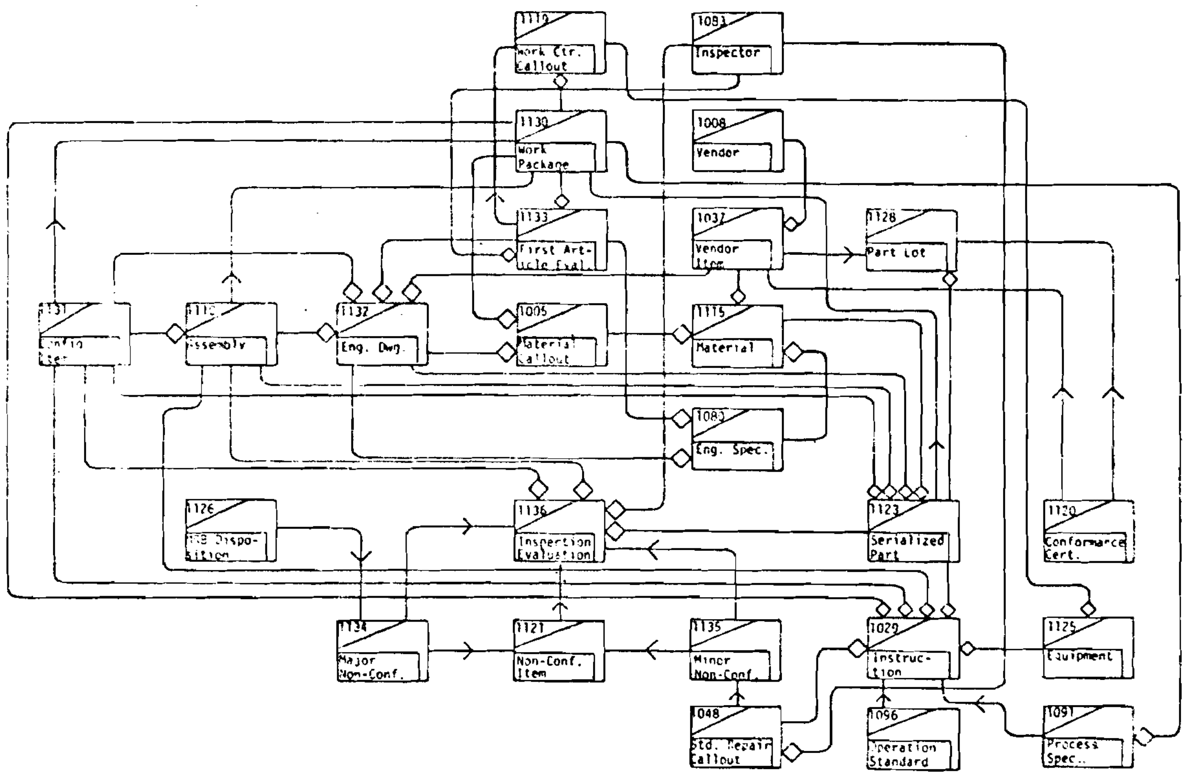


Figure 3-77 Entity Class Function View

3.4.2.4 Establish Architecture Interface Integration (WBS 4.4.2.4)

The "Assure quality" architecture model was integrated with the master ICAM manufacturing (MFGØ1) and Design (DES), 1) models while working with personnel of the ICAM architecture Part III, Project Priority 1104. The results have been published in AFWAL-TR-82-4063, Volumes III, IV, V, and VI.

Figure 3-78 reflects a generic view of the product quality architecture interface approach with manufacturing and design architectures. Figures 3-79 and Figure 3-80 illustrate QAØ interface with MFGØ and DESØ nodes, respectively. The QAØ Node Chart shown in Figure 3-81 illustrates the flow of the various functions as they integrate into each other. Figure 3-82 shows the production flow of General Dynamics F-16 line as the various components and assemblies are integrated into the final aerospace product.

3.4.2.5 Establish Improvement Concepts (WBS 4.4.2.5)

The System Requirements Document (SRD110513000) translated the needs identified in the Needs Analysis Document into systems requirements capable of satisfying those needs. Each need was reviewed in terms of suitable improvement concepts. The original draft was reviewed by Vought and General Dynamics who recommended several changes which were incorporated into the final draft. The final draft was submitted to the Air Force on 24 September 1982 and approved on 5 July 1983. The Systems Requirements Document was reviewed by industry and several changes recommended were incorporated prior to final approval by the Air Force PMO.

The System Requirement Document (SRD) provided:

- A set of improvement concepts that addressed the integrated factory QA/QC environment

- The system requirements that serves as a basis for understanding what is to be accomplished if the needs of quality in the Factory of the Future are to be met

- A basis for tracking future implementation programs.

The SRD further described the specific QA/QC performance requirements to be satisfied by the QA/QC "TO BE" System. This document was divided into four major sections as follows:

1. Identified how the system requirements and improvement concepts were developed for each key area of need as listed in the QA/QC Needs Analysis Document.

2. Identified the specific system requirements and improvement concepts for each key area of need. These areas were grouped into the following categories:

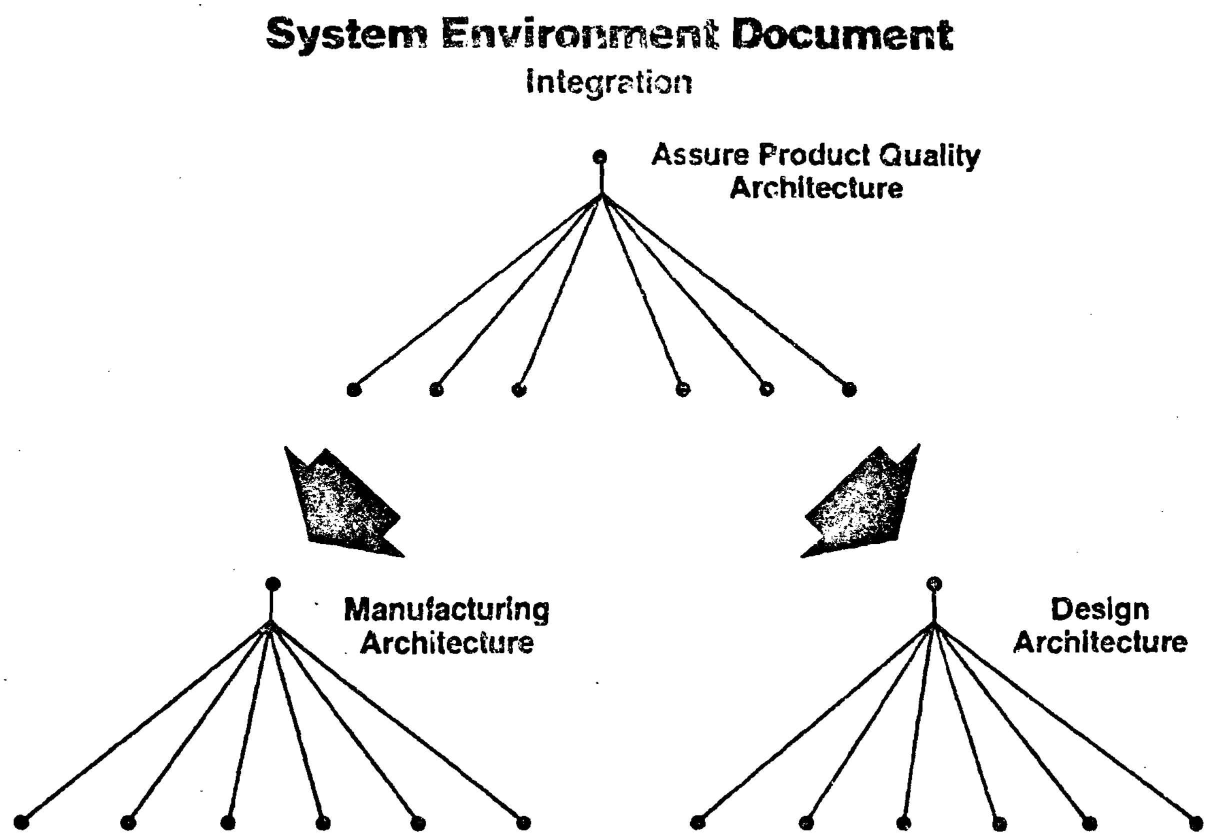


Figure 3-78 Generic Product Quality Interface Architecture

MFGØ	QAØ
A1 Plan for Manufacture	
A12 Estimate Requirements, Time and Cost to Produce	
A121 Estimate Resource Needs	A23 Develop Draft QA Program Plan
A14 Develop Support Activity Plans	A3 Prepare QA/QC Program Plan
A141 Develop QA Plan	
A1411 Establish QA Requirements for Production	A31 Issue Quality Requirements
A1412 Define Required QA Resources	A32 Specify Required QA/QC Resources
A1413 Issue QA Plan	A34 Issue Quality Plan
A2 Make and Administer Schedules and Budgets	
A21 Develop Master Schedule	A33 Establish Schedule
A22 Develop Coordinating Schedules	
A224 Develop Schedules for Continuing Support Activities	A33 Establish Schedule
A3 Plan Production	
A33 Develop Production Instructions	
A33333 Add Inspection Steps	A42 Provide QA/QC Detailed Work Instructions
A3343 Plan Receiving Inspection	A315 Issue Quality Requirements
A4 Provide Production Resources	
A42 Provide Equipment	
A4225 Checkout	A43 Calibrate and Certify Tools and Equipment
A4243 Perform Inspection	A43 Calibrate and Certify Tools and Equipmen
A4211 Perform Station Capability Analysis	A52 Verify Processes
A5 Obtain Manufacturer's Material	
A53 Inspect	A511 Perform Incoming Inspection
A6 Produce Product	
A63 Perform Physical Production	A512 Inspect Detail Parts
A6314 Inspect Detail Parts	A513 Inspect Composite Parts (Sub-Assemblies)
A6324 Inspect Composite Parts (Sub-Assemblies)	A514 Inspect/Test Major Assemblies and Installations
A6334 Inspect or Test Major Assemblies & Installations	A54 Control Nonconforming Material
A6315, A6325, A6335 Handle Nonconforming Materials/Assemblies	A515 Test/Checkout Aerospace Product (Final Product)
A64 Test Checkout	

Figure 3-79 QAØ - Integration with MFGØ

DESØ		QAØ	
A1	Develop Conceptual Designs		
A12	Analyze Customer Requirements		
A121	Define Requirements	A11	Idenfify Probable Future QA/QC Requirements
A1222	Compare Requirements with State-of-the-Art Technology	A12	Compare Future Needs with Existing Technology
A13	Formulate Concepts		
A1311	Review System Concepts	A12	Compare Future Needs with Existing Technology
A2	Develop Preliminary Design		
A21	Refine Candidate Configurations		
A2151	Verify Completeness of Performance, Design & Test Requirements	A21	Extract RFP QA/QC Requirements
A22	Select Optimum Configurations		
A2241	Update Integrated Test Plan and Correlate Design Requirements	A23	Develop Draft QA Program Plan
A2333	Confirm System Trade-offs and Producibility	A221	Evaluate RFP for Technology Requirements
A3	Develop Detail Design		
A311	Review Preliminary Design	A314	Determine Production QA/QC Requirements
A3321	Release Design Data	A315	Issue Quality Requirements

Figure 3-80 QAØ - Integration With DESØ

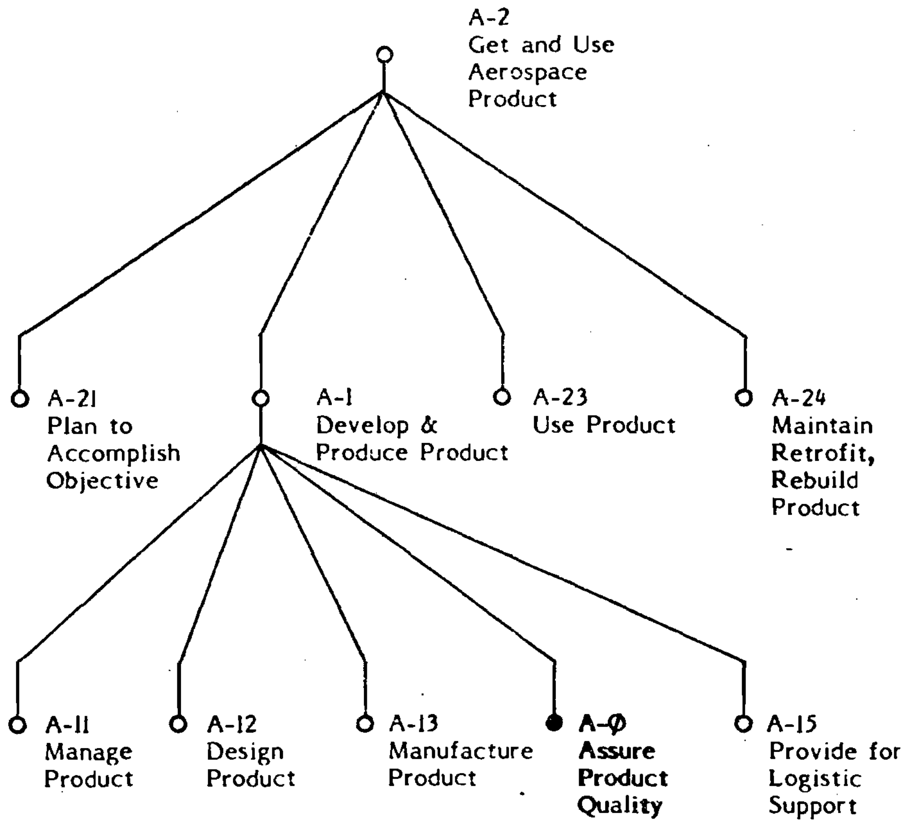


Figure 3-81 QAØ Node Chart

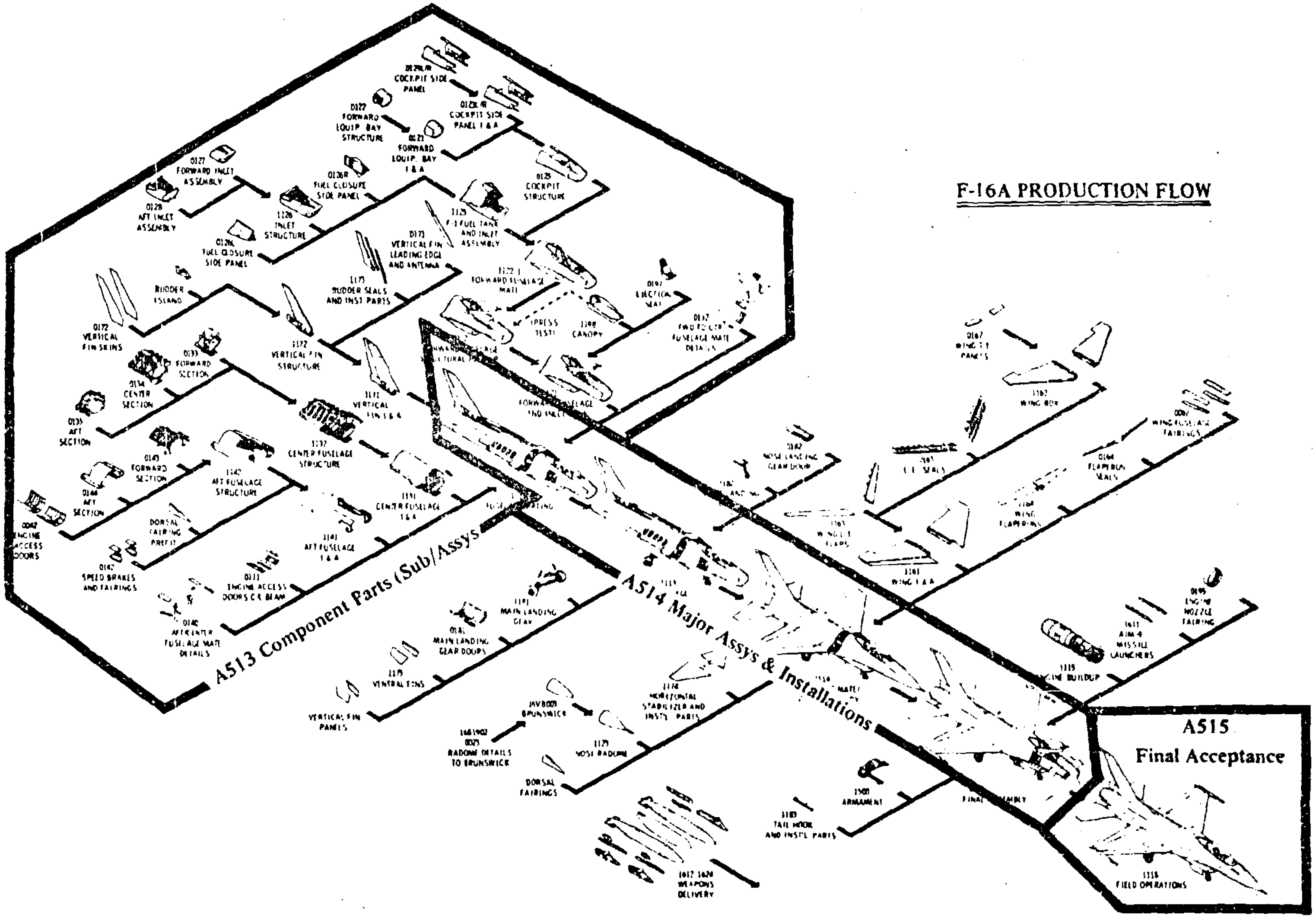


Figure 3-82 Perform Test, Inspect and Evaluation (FEO)

- o Early integration of functional activities
- o Providing fast, reliable inspections
- o Timely transmission of data
- o More effective personnel practices and resource allocation
- o Additional procedures for the "AS IS" quality system.

3. Identified what other ICAM systems might be impacted if the QA/QC system requirements were met

4. Identified those portions of the QA/QC IDEF0 activity diagrams that will be affected when improvement concepts are implemented to meet the system requirements.

Figure 3-83 is a partial listing from the System Requirements Document that illustrates how key areas of needs are defined, how they relate back to paragraphs in the Needs Analysis Document, and the relevant IDEF0 nodes to which they appertain.

The specific system requirements and improvement concepts section of the document defined each system requirement, proposed an improvement concept, discussed the availability of state-of-the-art techniques and approaches, established relevant effected nodes, and estimated the potential cost savings. Figure 3-84 is an example of the details describing system requirements referenced in figure 3-83.

Also discussed in the SRD is the potential impact QA/QC requirements might have on other ICAM systems. It points out that this impact must be considered in future planning because if the solution to QA/QC problems were implemented separately, they might create costly and time consuming incompatibilities.

3.4.3 Establish QA/QC Manual (WBS 4.4.3)

The objective of the QA/QC Manual was to provide a standardized approach for modeling, analyzing and improving "AS IS" QA/QC functions in industry. From this document, industry and DoD will be able to start from a developed QA/QC baseline and follow a logical, structured approach. This manual also identified common QA/QC functions and illustrated how integrated "TO BE" models and architectures were evolved for improvement concepts.

The completed document was entitled "Architecture for Product Assurance." It was developed by organizing and simplifying the output of the standard ICAM documents produced as part of understanding today's "AS IS" environment and putting that information into an easy, readable format. The document contains simple instructions on how to build a model. It contains the composite function IDEF0 and information IDEF1 models for "Assure Product Quality" with simplified directions for how to read and interpret the models.

The "Architecture for Product Assurance" also contains a summary of the Needs Analysis Document and the System Requirements Document with a brief explanation of how those two documents were developed.

PARAGRAPH IN NEEDS ANALYSIS DOCUMENT	KEY AREAS OF NEED	RELEVANT IDEF0 NODES
3.3.2.1	Needs Associated with the Integration of Assurance of Quality.	
3.3.2.1.1	Early prevention/detection of Design/ Production/Manufacturing problems and capitalizing on Quality opportunities.	A11
3.3.2.1.2	New QA/QC technology compatible with future design concepts and Factory-of-the-Future manufacturing innovations.	A14, A32 A34, A43
3.3.2.1.3	Utilize present Product problem data in future designs and change proposals.	A56
3.3.2.1.4	Early availability of Design and Manufacturing requirements for Test and Inspection planning and Equipment requirements.	A32, A34 A43
3.3.2.1.5	Reduce QA/QC resource inefficiencies associated with project organizations.	A2
3.3.2.2	Needs Associated with QA/QC Equipment.	
3.3.2.2.1	Inspections of internal integrity of composites.	A51214
3.3.2.2.2	Composite dimensional inspections.	A51231
3.3.2.2.3	Detailed machined part dimensional inspection.	A5122
3.3.2.2.4	Electrical wire harness inspection.	A5132

Figure 3-83 QA/QC Key Areas of Need

3.1.2.2.2 Fast, reliable inspection of internal composite Dimensions.

System Requirement:	The inspection of composites during the lay-up process is a continuous effort. Since the tape is opaque, each layer must be inspected for tape orientation and spacing. The inspection is manual and must be repeated for each layer. As a result, Quality Assurance is very labor intensive and time consuming. This problem exists in both tape and broad goods lay-up. A fast, reliable in-process inspection of composite materials is needed that will reduce the time and cost 60 to 75%.
Improvement Concept:	Integration of the inspection function with the tape and cloth lay-up to assure, rather than just inspect for, tape orientation and spacing. This would be a part of the automated lay-up program.
Improvement Concept State-of-the-Art Status:	Not Available There are some potential methods that show promise including x-ray, cat scan, and sonic scan.
Key Area of Need:	Composite dimensional inspections.
Paragraph & Page No. in NAD110513000	3.3.2.2.2, Page 3-25
Relevant IDEF0 Nodes:	A51231
Benefits:	$25 Million (3.4% of the savings)

Figure 3-84 Improvement Concepts Example

In developing this document, the coalition (General Electric, Vought, Northrop, and General Dynamics) took into consideration that there could be no pat answers nor tailormode guides for individual industrial businesses for obtaining instant solutions to quality and productivity problems.

However, this document does simplify the process considerably by providing a logical path to sequence events, prioritize those operations that merit immediate attention, eliminates duplication of procedures and establishes a road map that is designed to be both pertinent and flexible. The basic guidelines set forth in this document are designed to help industry achieve the quality and cost efficiencies it desires without the burden of immediate, overwhelming expense.

3.4.4 Establish Product Assurance Program Standard (WBS 4.4.4)

The four documents produced during the first phase of this project, "Understand Today's "AS-IS" QA/QC Environment", provided the background for the development of the Product Assurance Program Standard. This data, however, presented a limited point of view since the coalition had focused on Quality Assurance in aerospace manufacturing. Further, the data was presented from the perspective of the Quality Program/Project Manager.

The data base was expanded further by:

- Contacting Air Force suppliers who provide other products
- Contacting other DoD contractors who provide Army and Navy supplies
- Contacting other Air Force and DoD personnel
- Contacting the highest ranking Quality Assurance officers in industry and the military.

The coalition was then able to combine its working level data with "policy makers" data.

A questionnaire was developed to capture data in an organized and structured manner. This data was analyzed along with the feedback from personal interviews. Specification MIL-Q-9858A and related documents were also analyzed and problem areas and deficiencies were identified.

The Product Assurance Program Standard document includes consideration for integrated automated management and production systems applicable to current and near-future manufacturing environments.

Figure 3-85 summarizes the coalition's approach to developing the Product Assurance Program Standard.

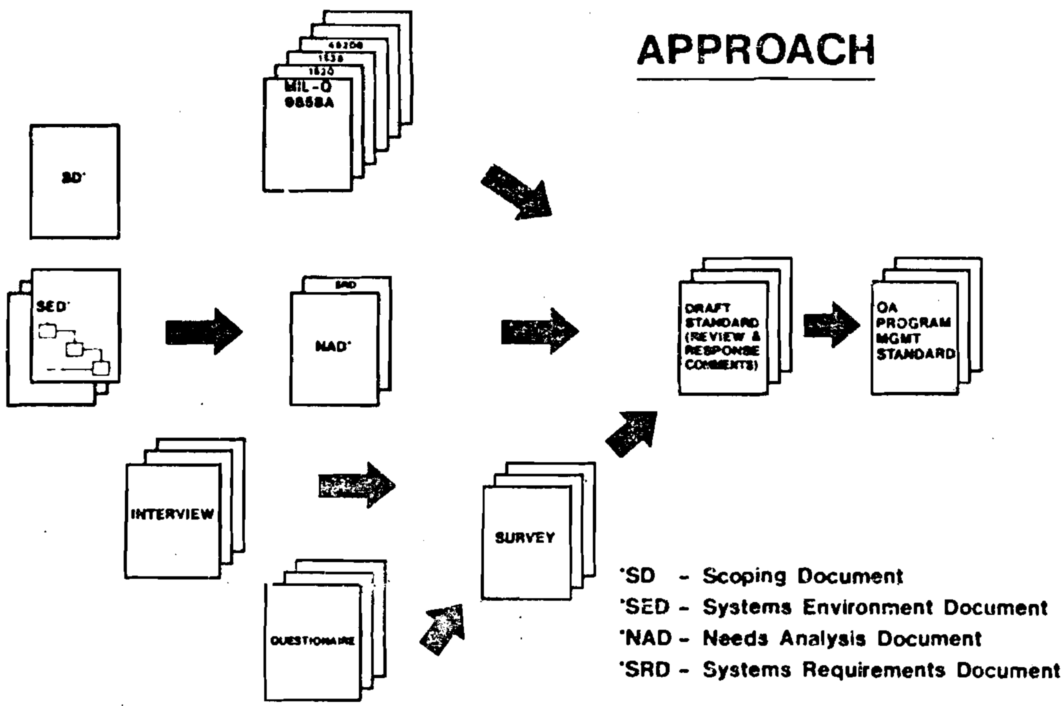


Figure 3-85 Product Assurance Program Standard-Approach Summary

3.5 (WBS 6.0) Special Considerations

3.5.1 Industry/Government Debriefing (WBS 6.2)

The Project 1105 prime contractor sponsored an end of contract debriefing at the Loews Anatole Hotel on 21 June 1984. The purpose of this debriefing was to transmit the salient results of the Project 1105 effort to appropriate representatives from Industry and Government. Invitations were extended to approximately four hundred people and approximately 200 attended. Names were obtained from a list supplied by the Air Force PMO.

3.5.2 Annual ICAM Industry Day Participation (WBS 6.8)

The coalition participated in two ICAM Industry Days as follows:

- o Sixth Annual Industry Days, New Orleans, Louisiana, January 1982
- o Seventh Annual Industry Days, New Orleans, Louisiana, June 1983

Plans are currently underway to participate in the Eighth Annual Industry Days to be held in Dallas, Texas 9-12 April 1985.

SECTION 4.0

REFERENCE DOCUMENTS

SECTION 4

REFERENCE DOCUMENTS

4.1 Abstracts of Approved Life Cycle Documents

The following paragraphs describe the approved life cycle and supplementary documents that have been produced on Project 1105. These documents may be ordered by using the Document Request Form found at the end of Section 4.

4.1.1 Task B Approved Life Cycle Documents

(1) Task B - Scoping Document (SD), "Factory of The Future Conceptual Framework," 25 March 1982, (SD 110512000), Volume II, Part 1, AFWAL-TR-84-4020

This document states the objectives of Task B, relates the objectives to specific work statements by defining the bounds of the project tasks and defines where the project correlates with the ICAM Architectures of Manufacturing and Design. For Task B, the two major objectives are: to establish an overall conceptual framework structure of upper level management functions supported by concept descriptions/definitions and limited architectures; and to establish a long-range, systematic strategy for initiating concept descriptions.

(2) Task B - Needs Analysis Document (NAD), "Factory of the Future Conceptual Framework," 10 May 1982, (NAD110512000), Volume II, Part 2, AFWAL-TR-84-4020

This document identifies "NEEDS" in the current "AS IS" factory environment in order to conceptualize opportunities for improvement. Seven major categories of needs were identified. The needs are related to: Information Resource Management, Management of the Factory, Product Definition and Planning, Product Assurance, Human Resource Management, Materials Management, and Financial Management. The document then relates (in a series of matrices) how these needs categories apply to the generic functions of the Factory of the Future detailed in the Scoping Document.

(3) Task B - State-Of-The-Art Document (SAD), "Factory of the Future Conceptual Framework," 20 September 1982, (SAD110512000), Volume II, Part 3, AFWAL-TR-84-4020

This document outlines the state-of-the-art technology which is applicable to the FoF environment being studied by the Task B coalition. The SAD was investigated from the perspective of information/communication/computer tools which support the factory management level decisions and the interface of this level to all other functions of the factory. Since the FoF is envisioned for the 1995 time-frame, this SAD analysis included not only current technology but, also leading edge technology which has a potential for demonstrating cost effectiveness. A detailed description of a leading computer integrated factory

(Ingersoll Milling Machine Company) is also included. The appendices contain a summary of selected data base management systems, a review of other ICAM SADs and their relationship to the FoF, and finally, a statement of compatibility of the SAD with IPAD findings.

(4) Task B - System Requirements Document (SRD), "Factory of the Future Conceptual Framework," 3 March 1983, (SRD1105120000), Volume II, Part 4, AFWAL-TR-84-4020

This document outlines the requirements and concepts for the enhancement of the aerospace factory operations in 1995. The document relates these requirements using the seven major categories identified in the NAD. These are: Information Resource Management, Management and Control, Product Definition and Planning, Product Assurance, Human Resource Management, Materials Management, and Financial Management. This document identifies these requirements for the Generic Factory of the Future and establishes the basis for developing the Factory of the Future Conceptual Framework.

(5) Task B - System Specification Document (SS), "Factory of the Future Conceptual Framework," 14 October 1983, (SS 1105120000), Volume II, Part 5, AFWAL-TR-84-4020

This document expands and further details the major requirements identified in the Systems Requirements Document (SRD1105120000). This document views the system in terms of specific system requirements and provides sufficient criteria to enable an initial conceptual design of the FoF.

(6) Task B - Conceptual Framework Document, "Factory of the Future Conceptual Framework," 10 February 1984, (MMR110512000), Volume II, Part 6, AFWAL-TR-84-4020

This document describes an approach for achieving computer integrated manufacturing in the 1995 aerospace Enterprise using the concepts developed in the SRD and SS. The aerospace Enterprise (factory) is described as a total system. It is broken down using System Engineering Methodology into its component parts; goals are reviewed; the operating environment of the 1995 time-frame is discussed; its principles of operation are defined and its functions are described. Detailed description of the major factory components are presented in the discussion. These components are examined from the physical view (people, production tools and equipment, facilities and the computer integrated factory network) and the logical view (common data base and logical processes used to manipulate data/information). The conceptual framework is based upon concepts previously developed and, as such, represent a hypothetical view. The document also points out that, a different description is possible if the actual parameters of a specific Enterprise were used as opposed to the generic concepts used by the coalition.

4.1.2 Task C and E Approved Life Cycle Documents

(1) Task C - Scoping Document (SD) "Integrated Composites Center Conceptual Design," 30 June 1982, (SD 110511000), Volume III, Part 1, AFWAL-TR-84-4020

This document states the objectives of Task C, relates the objectives to specific work statements by defining the bounds of the project tasks and defines where the pro ct correlates with the ICAM architectures of Manufacturing and De sign. For Task C, the two (2) major objectives are: to establish the needs equirements for an integrated composites center concept (basic effort), and to establish The Integrated Composites Center specification, preliminary design and implementation plans for the minimum of two (2) different manufacturing locations (Option 2).

(2) Task C - Needs Analysis Document (NAD), "Integrated Composites Center Conceptual Design," 30 April 1982, (NAD110511000), Volume III, Part 2, AFWAL-TR-84-4020

The purpose of this document is to identify shortcomings in the "As Is" composites manufacturing systems and to conceptualize possible opportunities for improvement. Fourteen categories of needs were identified. The needs are related to part design, rate and volume requirements, and position on the learning curve. Design, quality assurance, and tooling were identified as very large cost drivers. The needs do not vary much from company to company. Control is fragmented - integration is lacking; management and control systems were found to be inadequate.

(3) Task C - System Environment Document (SED), "Integrated Composites Center Conceptual Design," 31 May 1982, (SED110511000), Volume III, Part 3, AFWAL-TR-84-4020

This document provides the systems environment for the Integrated Composites Center (ICC). It consists of IDEFØ abd IDEF1 Composite Models of "AS IS" system and represents a generic environment of composites airframe manufacturing in the current aerospace industry. It identifies the commonalities found in today's environment rather than the idiosyncrosies. Northrop's, Vought's, General Dynamics' and, to a lesser extent, General Electric's, Approach to composites manufacturing were studies. IDEFØm 1 and 2 models reflect a compositing or synthesizing of these approaches. The models were constructed from these studies and validated through IDSS simulation. These models and the understanding of the "AS IS" compoistes environment gained in the data collection and modeling process were used to construct the System Environment Document.

(4) Task C - State-of-The-Art Document (SAD), "Integrated Composites Center Conceptual Design, 31 May 1982, (SAD110511000), Volume III, Part 4, AFWAL-TR-84-8020

This document establishes a point of departure for the design of the "TO BE" Integrated Composites Center by examining the technology of the "AS IS" environment. The coalition team analyzed their own current composite fabrication environment and also visisted the production facilities of other aerospace factories engaged in the fabrication and assembly of composites. Currently available technologies were examined to satisfy existing needs and technological voids were uncovered. These voids were described and prioritized in terms of cost drivers, performance drivers and human factor considerations.

(5) Task C - System Requirements Document (SRD), "Integrated Composites Center Conceptual Design," 31 July 1982, (SRD110511000), Volume III, Part 5, AFWAL-TR-84-4020

The System Requirements Document (SRD) was the first functional document of the "TO BE" Integrated Composites Center. It was the initial statement of validated "needs" for the "TO BE" center expressed in terms of requirements. These requirements were "needs" with associated parameters. This document identified the major requirment categories of the "TO BE" ICC which were traceable back through all of the previously produced documents of the ICC. The coalition individually analyzed their requirements to improve their specific composite production system. The resulting information extracted from these requirements which were generic to the aerospace industry are reflected in this Systems Requirement Document.

(6) Task E - System Specification Document (SS), "Integrated Composites Center Conceptual Design," 30 November 1982, (SS 110511000), Volume III, Part 6, AFWAL-TR-84-4020

This document contains the functional and performance specifications for the Integrated Composites Center System. It includes the specifications for a generic ICC as well as specifications tailored to Northrop, Vought and General Dynamics. The purpose of this document is to detail the system requirements to the maximum extent possible, to assure the reliability and validity of the requirements and to promote a basic understanding between the user and the contractor before system design begins. These specifications include a first-cut identification, description and appropriate models of the subsystems, cells and stations which will comprise the "TO BE" ICC.

(7) Task E - System Design Specification Document (SDS), "Integrated Composites Center Conceptual Design," 28 February 1982, (SDS110511000), Volume III, Part 7, AFWAL-TR-84-4020

This document addresses how each requirement presented in the System Specification will be addressed. Eleven cells or systems that encompass the entire gamut for composite fabrication and subassembly for both the generic and site specific centers are identified. These eleven cells are further identified by major Configuration Items and subordinate Configuration Items that satisfy each system requirement. These Configuration Items must be fully developed and exploited to conceptually satisfy system requirements. All Configuration Items are specifically defined as to their function within the ICC.

(8) Task E - System Test Plan Strategy Document (STP), "Integrated Composites Center Conceptual Design," 31 August 1983, (STP110511000), Volume III, Part 8, AFWAL-TR-84-4020

This document contains the System Test Plan Strategy for the Integrated Composites Center. It is written at the system level. It describes the concepts, criteria, standards, tools and strategies for testing the system at the conceptual level. The plan includes the Development, Testing and Evaluation (DT&E) of the system, as well as strategies for installation, checkout and technical demonstrations. It also addresses the validation of the Users, Operators and Maintenance Manuals. This document also contains three Appendices which describe the System Test Plan Strategies which are unique to Northrop, Vought and General Dynamics.

(9) Task E - Development Specification Document (DS), "Integrated Composites Center Conceptual Design, 30 June 1983, (DS 110511000), Volume III, Part 9, AFWAL-TR-84-4020

The Development Specification (DS) for the Integrated Composites Center decomposes specific configuration items requirements to a level sufficient to enable the evolutionary development of a detail design. It also identifies interfaces that will be accommodated by the subsequent design of the configuration item. This specification establishes the performance, development and test requirements for the hardware which makes up the ICC. The Development Specification was published as two separate documents. Volume I describes a generical ICC. This is a conceptual design only, not a precise framework. Volume II, Appendices, deals with specific requirements tailored to Northrop, Vought and General Dynamics.

(10) Task E - Implementation Plan Strategy Document (IP) Integrated Composites Center Conceptual Design, 31 October 1983, (IP 110511000), Volume III, Part 10, AFWAL-TR-84-4020

This document contains the conceptualized Implementation Strategy for the ICC. It describes the concepts, criteria, standards, tools and strategies for implementing the system. It describes the specific steps which must be taken to implement this composites technology into new or existing production facilities. This document includes implementation plans for a generic ICC as well as detailing specific factory implementation plans required by Northrop, Vought and General Dynamics

4.1.3 Task D Approved Life Cycle Documents

(1) Task D - Scoping Document (SD), "Quality Assurance/Quality Control Technical Requirements/Tasks," 28 January 1982, (SD 110513000), Volume IV, Part 1, AFWAL-TR-84-4020

This document states the objectives of Task D, relates the objectives to specific work statements by defining the bounds of the project tasks and defines where the project correlates with the ICAM Architecture of Manufacturing and Design. For Task D the three major objectives are: to establish an understanding of QA/QC activities required in aerospace production; to establish an ICAM Quality Assurance Manual that will provide a standard approach for modeling, analyzing and improving QA/QC technology in industry; and to establish a prototype Product Assurance Standard that will provide product assurance management guidelines in integrated/automated manufacturing environments.

(2) Task D - Needs Analysis Document (NAD), "Quality Assurance/Quality Control Technical Requirements/Tasks," 24 June 1982, (NAD110513000), Volume IV, Part 2, AFWAL-TR-84-4020

This document assesses the "AS IS" manufacturing environment shortcomings with respect to the quality assurance/quality control requirements and tasks. Needs are analyzed in terms of human factors issues and cost/performance drivers. The major needs categories are comprised of specific need descriptions. The categories utilized are: integration of quality assurance, QA/QC equipment, QA/QC information handling, technical skills, and software quality assurance. The coalition prioritized the needs overall, as well as within each category, based on anticipated benefits to be derived from systems improvements.

(3) Task D - System Environment Docment (SED), "Quality Assurance/Quality Control Technical Requirements Tasks," 31 August 1982, (SED110513000), Volume IV, Part 3, AFWAL-TR-84-4020

This document presents the IDEF0 and IDEF1 factory and composite view models which describe the Quality Assurance/Quality Control activities and related information in today's aerospace manufacturing environment. These models provide a broad baseline understanding of "AS IS" QA/QC functions and serve as a foundation for developing computer integrated QC systems. The models were designed to be integrated into the DES0 and MFG0 architecture, as appropriate. The information model concentrated in six key quality areas and added valuable insight and information to the understanding of quality activity modeling. Twenty-five activity classes and twenty-four key attributes were identified as a result of this effort.

(4) Task D - Systems Requirements Document (SRD), "Quality Assurance/Quality Control Technical Requirements/Tasks," 24 September 1982, (SRD110513000), Volume IV, Part 4, AFWAL-TR-84-4020

This document identifies a series of improvement concepts that address the integrated factory QA/QC environment. It also provides the system requirements that must be satisfied which will serve as a basis for understanding what is to be accomplished if the needs are met and a basis for tracking future implementing programs.

(5) Task D - Architecture for Product Assurance, "Quality Assurance/Quality Control Technical Requirements/Tasks," 10 January 1984, (TTD110513000), Volume IV, Part 5, AFWAL-TR-84-4020

This document presents the findings of the coalition in providing a working model whose benefits go beyond aerospace boundaries to establish applications in virtually every manufacturing situation. It provides a technology baseline for assessing and planning modernization and integration of Product Assurance in today's manufacturing environment. It becomes a starting point for a manufacturer to assess his current situation and to determine what steps should be taken to assure quality and productivity increases throughout the entire manufacturing cycle, from design and engineering to finished product and field use.

(6) Task D - Product Assurance Program Standard, "Quality Assurance/Quality Control Technical Requirements/Tasks," 18 August 1982, (ISP110513000), VOLUME IV, Part 6, AFWAL-TR-84-4020

This document includes considerations for integrated automated management and production systems applicable to current and near future manufacturing environments. Background and other supporting material, including approach and survey results, are also presented. Three paths were explored to help define the requirements for this standard. First, an in-depth review of applicable military, government, and industry QA/QC publications was made. Second, the Understand the Problem document was referenced for usable elements of standards ramifications. Finally, the coalition solicited feedback from government and industrial sources on current and anticipated future requirements. Together, this data comprised the information for this document.

4.2 Displays

An ICAM Industry Day display booth was designed as part of the ICAM Conceptual Design for Computer Integrated Manufacturing project. The design was reviewed by the Air Force PMO and revised in accordance with their comments. This display was finalized and set-up at the Sixth Annual ICAM Industry Days held 17-20 January 1983 at the Marriott New Orleans Hotel in New Orleans, Louisiana. This display has been used at the following locations:

- MTAG, Orlando, Florida
- Boeing Military aircraft Company, Wichita, Kansas
- Headquarters Aeronautical Systems Division, Wright-Patterson AFB, Ohio
- Texas A&M University, College Station, Texas
- End-of-Contract debriefing, Dallas, Texas
- LTV Aerospace and Defense Company, Dallas, Texas

Photographs of the display are shown in Volume V, Appendix F of the Final Technical Report.

4.3 Ordering Approved Life Cycle Document

Use the Request Order Forms at the end of this volume to request copies of the Approved Life Cycle Documents. Send requests to:

ICAM Program Library
AFWAL/MLTC
Wright-Patterson AFB, Ohio 45433

The Final Technical Report, AFWAL-TR-84-4020, can also be requested from the Defense Technical Information Center (DTIC). Send requests to:

DTIC
DDR-1
Cameron Station
Alexandria, VA 22314

APPENDIX A

FACTORY OF THE FUTURE CONCEPTUAL FRAMEWORK REVIEW

Ambassador Room
Daytonian Hilton
Dayton, Ohio
4-5 May 1983

This appendix contains the results of a Factory of the Future Conceptual Framework Review of Project 1105 conducted by a "Super Coalition" of noted manufacturing and computer experts conducted at Dayton, Ohio, 4-5 May 1983.

This appendix was originally published as part of Interim Technical Report, ITR110510007U, dated 15 July 1983. Because ITR110510007U will not be published further for general distribution and the importance of the review, it is repeated here for the convience of the reader.

3.0 TASK B REVIEW MEETING FACTORY OF THE FUTURE

3.1 Agenda

AGENDA
FACTORY OF THE FUTURE CONCEPTUAL FRAMEWORK
REVIEW
AMBASSADOR ROOM
DAYTONIAN HILTON
DAYTON, OHIO

OBJECTIVES:

1. Provide a summary of Task B to establish the basis for analysis of these results by the review team.
2. Based upon the review and received documentation, have the review team assess task results, and identify: areas of agreement, areas of concern and, if required, additional areas for consideration.
3. Have each review team provide a written report on their position by 20 May 1983. This report should emphasize suggestions for improving the concepts being developed by the Task B coalition.

Wednesday, May 4, 1983

8:30AM	Welcome and Introductions	Capt. R. R. Preston ICAM PMO
8:45AM	Project 1105 Overview and FOF Conceptual Framework Scope	D. L. Norwood Vought Corporation
9:25AM	FOF Conceptual Framework Needs Analysis	A. W. Snodgrass D. Appleton Co., Inc.
10:10AM	Break	
10:25AM	FOF Conceptual Framework Requirements	R. L. Moraski Vought Corporation
11:20AM	FOF Conceptual Framework State-of-the-Art Investigation	R. L. Diesslin IIT Research Institute
12:00NOON	Lunch Break	

Wednesday, May 4, 1983 (continued)

1:00PM	Working session to provide the Review Team the opportunity to discuss Task B and formulate suggestions for improvement. This session will concentrate on the requirements for the Factory of the Future.	H. Buffum J. Harrington J. Lardner W. Skinner R. Spears
2:15PM	Break	
2:30PM	Working session continued	
5:00PM	Adjournment	

Thursday, May 5, 1983

8:30AM	Open discussion on the Conceptual Framework for the FOF	All attendees
10:30AM	Break	
10:45PM	Review of the working session based upon the open discussion inputs and further reflection.	Review Team
12:00Noon	Lunch Break	
1:00PM	Recommendations for next meeting	R. L. Moraski Vought Corporation
2:00PM	Adjournment	

3.2 Attendance List

ATTENDANCE LIST

1105 Industry Review Meeting

Daytonian Hilton, Dayton, Ohio

4-5 May 1983

NAME	COMPANY & BUSINESS MAILING ADDRESS	MAIL STOP/ SYMBOL	TELEPHONE
Rick Preston ICAM Project Mgr	AFWAL/MLTC WPAFB, OH 45324		513/255-7371
Harvey Buffum	H. E. Buffum Co. 5439 So. Hudson Seattle, WA 98118		725-5040 293-6227
Don L. Norwood	Vought Corp.		214/266-5549
Dick Spears	Boeing Computer Services		316/526-2612
A. Wayne Snodgrass Vice-President DACOM	D. Appleton Co., Inc. 1104 Highland Avenue Manhatten Beach, CA 90260		213/318-2451
Laurence O. Ward Northrop Corp.	Northrop Corp. One Northrop Ave. Hawthorne, CA		213/970-5667
Ken Lillie Program Manager	AFWAL/MLTC WPAFB, OH 45433		513/255-6976
Carol Born Industry Fellow	AFWAL/MLTC WPAFB, OH 45433		513/255-6976
Gerald Shumaker Tech Area Manager	AFWAL/MLTC WPAFB, OH 45433		513/255-6976
James F. Lardner Deere & Co.	Deere & Co. John Deere Road Moline, IL 61265		309/752-5988
Gary Haug ICAM PMO	AFWAL/MLTC WPAFB		513/255-6976

NAME	COMPANY & BUSINESS MAILING ADDRESS	MAIL STOP/ SYMBOL	TELEPHONE
Rich Diesslin IITRI	10 W 35the Street Chicago, IL		312/567-4000
Joseph Harrington, Jr. Arthur D. Little, Inc.	Acorn Park Cambridge, Mass 02140		617/864-4770 x5431
Ken Mehlhope Cincinnati Milacron	4701 Marburg Ave. Cincinnati, OH 45209 AFML WPAFB, OH		513/255-6976
Wickham Skinner	Box 282 B St. George, ME 04857		207/372-6219

3.3 Minutes of Meeting

Attachment (A)

PROJECT PRIORITY 1105
TASK B F.O.F. INDUSTRY REVIEW
DAYTONIAN HILTON, DAYTON, OHIO
04 to 05 May, 1983

The Project Priority 1105, Task B Factory of the Future Industry Review was held at the Daytonian Hilton from 04 to 05 May, 1983. Attendees at this meeting were, as follows:

Coalition Members:	Panel of Experts:
Mr. D. Norwood, Vought Corp.	Dr. J. Harrington, Consultant
Mr. R. Moraski, Vought Corp.	Mr. H. Buffum, Consultant
Mr. R. Neal, Vought Corp.	Dr. W. Skinner, Harvard Business School
Ms. B. Davis, D. Appleton Co.	Mr. J. Lardner, John Deere & Co.
Mr. W. Snodgrass, D. Appleton Co.	Mr. R. Spears, Boeing Computer Services
Mr. L. Ward, Northrop	
Mr. R. Diesslin, IITRI	

ICAM PMO

Capt. Richard Preston
Mr. K. Lillie
Mr. J. Schumaker
Mr. K. Mehlhope
Ms. C. Born
Mr. G. Haug

The meeting was convened by Capt. Richard Preston, Project Leader, U.S. Air Force ICAM Program Office. Capt. Preston welcomed the participants of the meeting, particularly the industry experts who had been invited as representatives of the executive management level of industry and who would provide input to the Factory of the Future Project whose approach is to address factory management from the executive level to the center level.

Don Norwood, Program Manager, presented an executive summary of the objectives and approach of the entire 1105 Project. His presentation was followed by more detailed reviews of the documentation which was being assessed at this meeting. Specifically, A. Wayne Snodgrass reviewed the Needs Analysis document; R. Moraski reviewed the System Requirements Document; and Richard Diesslin reviewed the State-of-the-Art Document.

The remainder of the day was an open forum discussion which allowed the panel of experts to express their thoughts regarding the work which had been performed to date and their recommendations regarding future direction of the program.

These discussions were continued during the following day's session. Both Air Force participants and coalition members were given the opportunity to share their observations and concerns.

The following meeting minutes represent pertinent comments which were made during the meeting. In order to facilitate their readability, these comments have been categorized, as follows:

- Program approach
- Documentation: General Comments
- Documentation: Specific Comments
- Documentation: Future Recommendations
- Marketing the Technology

It was generally concluded by both the panel and Air Force that a very credible piece of work had been achieved by the coalition members and that future work should focus on a strategy to market the program's achievements.

Program Approach

o The project is to develop a credible model of a major set of integrated systems that can design and manufacture products more accurately and at a reduced cost. The approach should be from a systems basis, i.e., say what you want to see. Also, the system should be designed to handle data from design conception to logistics. Lastly, define the environment in which that system can operate (Jim Lardner)

o Many decisions to invest in technology are being made or are not being made for financial reasons. The internal reward systems are not responsive to long-term risk taking. In addition, people don't work necessarily for the company for six years. Younger people tend to move on. We, therefore, must address ourselves to internal management systems (Wickham Skinner).

o Plan is referenced with bottoms up implementation. Bottoms up method of systems development will not work and cannot be tolerated. Must have an overall plan (Harvey Buffum).

o "Top down/Bottoms up" means macro to micro. Each micro change must fit into a macro plan. Macro implementation, however, will produce total chaos. One cannot macro implement. Must change a large thing bit by bit. The inertia of invested capital is tremendous so you change a piece of it at a time. Must respect the science of manufacturing (Joe Harrington).

o There are three kinds of decision making in an organization:

(a) structured, i.e., feeds and speeds where there is a real application for the computer.

(b) semi-structured, i.e., trends etc., where the application of the computer may be helpful.

(c) un-structured, where the computer can't help at all.

The system should speak to structured decisions (Jim Lardner).

o Information flow will be the key. IRM will work. It is the future environment. Systems should be built to support program management (Dick Spears).

o The goals of the needs, such as reduced cost, improved quality, customer services, flexibility, and human resource management are not necessarily met by super integration. Need some good old-fashioned execution. That's what the Japanese do. The use of computers and integration results in complexity. Thrust is towards massive and total systems. Not certain this is correct. What is its purpose? Is the project's purpose educational? If so, what else is necessary? How do you teach these concepts to a culture of managers and technical people? (Wickham Skinner).

Documentation: General Comments

o The System Requirements Document is more realistic than any other ICAM documentation depicting what the aerospace industry really thinks and understands. The Documents have depicted the aerospace industry problems (Harry Buffum).

o Brilliant piece of work. So complete it represents a checklist and logic as to how to look at factory and factory systems. NAD is terrific, however, some misgivings whether the documentation can be used for meeting its intended need. The process of helping industry in this country realize the factory of the future goes a lot further than the best schemes, and best models, checklists, and analyses (Wickham Skinner).

A commendable job. Much work and good solid thinking (Joe Harrington).

o Good documents. Impressed with approach, especially in the IRM area (Dick Spears).

- Needs analysis document is well done. Good, programmatic view in that a need equated to a deficiency or void. In Systems Requirements Document, coalition has done a good job of identifying the systems requirements, but should sort out and prioritize the requirements (Jim Lardner).

- Life cycle documents have given structure to the program. They communicate the projects accomplishments to other enterprises (Capt. Richard Preston).

Documentation: Specific Comments

Needs Analysis Document

Human Integration, i.e., getting humans to work with the computer is not mentioned in the NAD (Joe Harrington).

Systems Requirement Document

- System Requirements Document is too large to be considered an effective sales tool. There is a need to identify benefits and cost savings (Ken Mehlhope).

- Too much philosophy in the System Requirements Document. Must pull requirements out of the philosophy, such that the requirements are clarified (Capt. Richard Preston).

- System Requirements Document needs to address in much greater detail, the configuration management which has in the past been a most disastrous failure in building weapon systems. Industry must know the exact configuration of each airplane over its life of 20 years and is faced with finding a method of keeping data containing many system and configuration changes. Configuration Management must be a key part of top down planning. The configuration control thread is not apparent in the SRD and needs to be addressed more thoroughly (Harvey Buffum).

- Management and political issues should be addressed more strongly since computers are used for political reasons (50%), logical reasons (25%), and data moving (25%) (Dick Spears).

- System Requirements Document has done a good job in identifying the requirements, but these requirements must be sorted out. Some of the requirements are more of a management problem as opposed to a systems problem. Others will be critical to an information resource management structure which can operate a "Factory of the Future" (Jim Lardner).

- The word factory is an abused term. Should use the work enterprise when talking about the entire organization (Joe Harrington).

- System Requirements Document reflects independence from one another. It's a quick compilation of group results.The Product Assurance section doesn't tune into the designing in of quality, but rather focuses on quality processes in the manufacturing operation. Quality Assurance must have a front end invested effort (i.e., procedures, configuration management). Must be included in definition planning and design phases. The Factory of the Future planning must recognize that QA fits in upfront (Capt. Richard Preston).

- Design and manufacturing must work together, but maintain independence as to responsibility so that decisions are not forced to one managers viewpoint (group discussion).

- Sort out real system requirements which are going to be essential to data flows that manage the derivation and integration of data into information. Data and information are not the same thing. Systems use data to provide information (Jim Larder).

State-of-the-Art Document

Disappointed with the SOA as presented and prepared. There are many managerial issues which must be addressed. One such example is the necessity of a new approach to financial management or ROI (Jim Lardner).

The life cycle of manufacturing process and software process are in parallel. The secret is in the building of data bases (Spears).

Documentation: Future Recommendations

- General

- You need simple examples, some numbers, some data, economics, and case histories. Utilize graphics to show what is better; how would you know; what is integration (Wickham Skinner)

- Need color brochure or a good sellable package to convince the champions (Ken Lillie)

System Specification

- Within each company there will exist different data and different systems. Use an example which depicts current Systems and the relationship of data. Show the transition from one company's present condition to the factory of the future in 1995 (Harvey Buffum).

- o We're looking for a credible model or a major set of generic strategy. Should simplify. Trying to say too much. Should suggest a particular organizational structure. The old organization structure is based on limitation of information. Should rethink the organizational structure (Wickham Skinner).

- o Pull out requirements and categorize requirements because not all the requirements can be addressed by systems (Jim Lardner). Categories are as follows:

  (1) Requirements which can be addressed by SOA technology systems, manipulation or resolution of an information problem

  (2) Requirements which must be addressed by a change in management

  (3) Requirements for which we need to do more research

  (4) Requirements for which technology does not yet exist (Jim Lardner)

Implementation Strategy Report

- o The report should be a dissertation on how to transmit a credible image to potential users (Joe Harrington).

- o Need to examples, such as "here's a way to do it or to think about it". An executive summary sort of thing (Wickham Skinner).

- o There's a need to lay out some type of scenario that will fit within the implementation strategy. We need an example company from which we can reflect how business is accomplished and how company will be able to build future operations using what's been developed on this program (Capt. Richard Preston).

- o Identify how a company operates from a systems viewpoint. A scenario case Apply developments from this project to that scenario case and build upon it (Harvey Buffum).

- o Possibly expand Ingersoll Case study.

- o We need a macro view of what's going to be different between today's operations and future operations. Key in on those major areas of change. Develop scenarios to discuss differences. Look at successful implementors of change. Define what are the implementation steps. Make clear assessment of these enterprises (books could be helpful). Look at companies who have moved the farthest. Look at the organizational changes. What was the role of top management. What role did CEO have in addressing resistance to organizational change. Also, look at failures to see what were the causes (Carol Born).

- We need something to promote the results of this project which will motivate readers.

- Implementation strategy should contain signposts or definite goals to be achieved each year (Ken Lillie).

- Define mechanism of technological evolution (Wickham Skinner).

- Implementation ought to be carried out in a novel manner. We'll be breaking down new ground (Joe Harrington).

Marketing the Technology

- Present State-of-the-Art Technology may be a real handicap. Islands of technology are available, but the integration technology to put it all together is not available. A possible cause of this technology void may be the lack of demand for integration technology. Simply, the management market is not ready. Therefore, the technology hasn't been developed (Wickham Skinner et al).

- There's a marketing job to convince management that you must do it (Jim Lardner).

- There's a critical need to sell what we have now (Harvey Buffum).

- If we are to meet Factory of Future objectives, IRM will demand senior management attention.

- Advantages of new technology are not in old-fashion productivity or cost savings. New technology will be adapted for flexibility so that more engineering changes can be made, more models, and more customer specials with shorter lead times. To focus on productivity in a broad sense may be counter-productive. Too hipped on productivity. "Competitivity" may be a better term. In other words, we should stress competitiveness (Wickham Skinner).

- CEO needs to understand the strategic issues and the competitiveness, not the technology (Jim Lardner).

- Managers don't always know what information they need or how to use it. There is a tremendous job of educating the manager, especially since there's been a lack of management involvement in the process (Jim Lardner).

- There's a significant problem in getting manufacturing management people to understand the problem and the needs. This lack of understanding will not be resolved by bringing these managers to a conference because directors will not ask questions in front of their staff, as they will not want to expose their lack of background. The selling job must be done on a one to one basis. It will remain difficult to communicate with directors until this is accomplished. We must also reach their technical advisors, i.e., manufacturing management (Harvey Buffum).

- The one on one approach is insightful. Do we change people through documentation, models, or deductive thinking? People will have to develop the concepts themselves (Wickham Skinner).

- If you wish to sell Computer Integrated Manufacturing to Industrial People, the ultimate transmission of information and conviction of a buyer is done on a one to one basis. Make 500 slides and call out a set of slides which fit customer needs, i.e., tailor the slide show to the individual. In such a way, we can attempt to transfer a full blown concept of a credible vision of what the factory in 1995 will be to the user (Buffum/Harrington).

- How can we get people to listen to us? How do we transfer technology?

  10% - creators of software, leaders and inventors of new technology

  <u>20%</u> - early adapters, gamblers, if it looks good

  30% - late adapters, if it works completely, will buy it off the shelf

  40% - reluctant dragons who will adopt only as an answer to bankruptcy

  It seems probable that it is the 20% early adapters which the coalition wishes to reach. We need to reach the Director of Operations or the Vice Presidents of Operations who will really control where those companies go and who are technical advisors to the Chief Executive Officers. We need a champion in the company to make it fly (Joe Harrington).

3.4 <u>Comments, James F. Lardner, VP Deere & Company</u>

This section contains the letter written by James Lardner to the 1105 coaltion concerning the meeting in Dayton, Ohio, on the 4-5 May 1983.

DEERE & COMPANY

JOHN DEERE ROAD, MOLINE, ILLINOIS 61265 U.S.A.

FTR110510000U
29 June 1984

JAMES F LARDNER
Vice President

3 June 1983

Mr. Don L. Norwood
Vought Corp.
P. O. Box 225907
Dallas, TX 75265

Dear Don:

I am sorry that I have not responded to your request for comment earlier. After our meeting in Dayton on 4-5 May I had intended to get this letter off immediately. Obviously other things interferred which prevented that.

In thinking over the things that I believe need to be considered as you refine your Systems Requirement Document, there are three areas that come to mind. The first is that to achieve Computer Integrated Manufacturing and the Factory of the Future we absolutely must address the data management problem. I think that in general your coalition has done a good job of identifying the majority of the elements involved in this problem. I do not think, however, that the problem itself is stated clearly enough for those who are not closely involved to understand what it is that all of the systems effort is expected to accomplish. I am thinking particularly of senior manufacturing executives, corporate officers, government decision makers, and so on.

While your diagram entitled, Factory Of The Future Framework, used throughout your presentation to illustrate Needs, is an excellent start I think it could stand considerable refinement to distinguish more clearly between the data management problem and the specific use of data to manage and control the transformation operations. An NC program is basically a highly distilled data set derived from a much larger, broader set or sets, most of which also serve many other needs. It is managing the process of creating, transforming, deriving, interpreting, transmitting, refining and distilling data that is going to be the key to integration. I think more work needs to be done in this area.

The second point of concern is the unevenness of problem identification, statement of functional needs and system requirements. A large portion of this is very well done but there is an important lack of specifics in many areas. I recognize that at this stage of the project there is still a great deal to be defined, but a number of objectives listed as systems requirements are far more manag‹ ment dependent than system dependent. There are also some objectives listed under system requirements for which insufficient technical knowledge is available to satisfy them. Sooner or later this fact will have to be recognized where it affects systems design.

My third concern, under functional needs and systems requirements, is that I am not sure that all of the functional needs that are listed represent the "to be" situation. In our experience at John Deere we have found that establishing needs on the basis of what people are doing today is a poor way to approach the problem. Where we have been successful is where we have determined: First—what is it people are trying to do: Second—should they really be trying to do that or should they be doing something else? Third—once it has been determined what people should be doing, it is necessary to establish the best way to get it done. We are so bound by the world around us that it is often difficult to recognize the problems we are solving should never have existed to begin with. This suggests that the Manufacturing Architecture (which most people agree is generic) is the proper basis for your approach to the Fac‹ ‹y of the Future to make sure you aren't solving problems that manufacturing organizations have invented and which are not really part of Manufacturing.

My final concern is the increasing evidence, in all parts of the ICAM program, that knowledge gained from the research done in other projects is not being applied sufficiently in associated or derivative projects. I cannot emphasize too strongly that the PDDI project is a critical element in the entire problem of data manipulation for manufacturing and it deserves your earnest attention.

I hope these comments will be of some help. I will be glad to discuss any of them with you if you feel that would be worthwhile.

Yours truly,

James Hardwick

JFL:pb

3.5 Comments, Wickham Skinner, Harvard Business School

This section contains the letter of comments written by Wickham Skinner to the 1105 coalition. Mr. Skinner attended a briefing of the 1105 project on 4-5 May 1983.

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May 20, 1983

Mr. Robert Moraski
FOF Project Manager
Vought Corporation
P. O. Box 225907
Dallas, Texas 75265

Dear Bob,

I enclose comments and suggestions concerning "Task B: Establishment of the Factory of the Future Conceptual Framework."

This report is submitted with great respect for the massive and thoughtful efforts invested by you and your colleagues in this challenging project. Since my assignment, however, was to "emphasize suggestions for improving" this document, I have allotted more space to such suggestions and ideas than to compliments, much as they are deserved.

Please call or write if you have questions.

Yours very truly,

Wickham Skinner

Wickham Skinner

WS/stl

Enclosures

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FTR110510000U
29 June 1984

COMMENTS AND SUGGESTIONS CONCERNING "TASK B: ESTABLISHMENT OF THE FACTORY OF THE FUTURE CONCEPTUAL FRAMEWORK"

I. SUMMARY

The "Task B" document is a remarkable achievement. It is an extraordinary collection which lists the tasks involved in manufacturing and verbally and pictorially diagrams their multitude of interconnections, internal dependencies, and logical relationships. As such it appears to be an extraordinarily complete taxonomy and, based upon its clearly ambitious objectives as to completeness and realism, it cannot be considered anything but an outstanding success.

In particular the document makes a superb and indeed unique contribution toward a new understanding of the factory as a data processing system rather than as an essentially physical operation which transforms materials into products. In this sense, the document's key contribution to the "factory of the future" is that one powerful idea.

The idea is of key importance: if managers and engineers are to take advantage of newly available technology and conceive, build, and successfully operate radically new factories which outperform the factory of today, they must change the present mind set. The present mind set, established two hundred years ago by new sources of power and mechanical machinery in the industrial revolution and reinforced by Frederick Taylor and generations of cost conscious managers, conceives of the factory as a "productivity machine" for transforming materials into products. With this premise the factory is planned for minimum direct production costs and governed by the principles of industrial engineering and concepts of "efficiency."

It is this seductive and habitual pattern of thinking which is not only directly causing problems today[1] but holding back progress in practical innovation leading to radical changes needed for a "factory of the future." When the factory is perceived by

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1. Today's problems include poor quality, high overhead and indirect costs, work force management tensions and conflicts, lengthy lead times, excessive inventories, shortages of skilled workers, the unattractiveness of the factory to outstanding young people, and the generally low esteem of the working population for the factory as an institution in which to invest one's career.

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investors and managers as a superbly designed and coordinated data processing operation to be used as a strategic competitive resource it will be designed, equipped and managed altogether differently than in the past. This Task B document may help many readers to shift their thinking in that direction and to the extent that that takes place it can be considered a success.

That issue of the extent of its impact is a serious one and it is the issue to which much of this report is now addressed. For I have considerable doubts that the Task B document as presently constituted will have nearly the influence or results that you, its authors, the Air Force, and your reviewers hope it will achieve. My reasons for these concerns will be detailed in the pages which follow. In summary, they have much to do with presentation and implementation strategy.

The presentation is essentially flawed by "overkill" - an excessive effort to be complete and exhaustive; it conveys an overpowering sense of being the product of believers and enthusiasts talking to each other. The implementation strategy which is not only set forth explicity in that section but, equally important, is buried implicitly throughout the entire document, seems to rely much more on the ideology of some inevitably great benefits of computer-integrated manufacturing than on any sober, realistic, appraisals backed by economic or case data setting forth not only costs and benefits but the absolutely enormous problems and risks facing corporations and managerial careers as we grope our way toward a future factory which can be a more successful institution.

Is this a fixable set of problems? I believe much can still be done and my suggestions are directed toward this purpose and intended to be as constructive as possible. Can your present coalition do the fixing? Here I am more pessimistic. Not only is it hard for authors to edit a major shift in tone and content into their own hard worked product, but I believe you will need some new resources - some strong, hard-nosed skeptics are needed to change the tone to a more balanced, realistic, nuts and bolts and facts and figures content. Your present group represent too much the optimistic believers, shakers and movers, the near religion of CAD/CAM/CIM and total integration. This changeover would be a big job; it comes late in the game, and you may well decide not to make that additional investment in spite of this advice and go with what you have.

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II. PROBLEMS, COMMENTS AND SUGGESTIONS

A. PRESENTATION

1. It's too much, too big, too thick, too complex. It is a catchall, totally overpowering, in an attempt to be complete and thorough and logical.

   It comes across as a committee effort in which every member's contributions have had to be respectfully honored. I believe the length and volume could be cut by 50%.

2. The tone is too dreamy and idealistic. It is one of believers writing to believers. It is a rhapsody of gypsy violins lilting into the twilight; it makes assumption upon assumption about the magical benefits of all that is proposed but offers few examples or even clear facts as to these advantages.

3. The presentation fails to cite many specific problems in debugging, start-ups, integration, costs, investments, break-even levels, and flexibility for changes in volume.

4. The report is logical and complete to the point of becoming an academically pure exercise of its own. In this sense it does become a cleanly compartmentalized thing of internal logic and beauty. But to the heathen, the skeptic, agnostic or disbeliever it may come across as a collection of wish lists.

5. The report lacks clear "how to do it" statements which could become bridges to its actual use.

6. What, indeed, is the potential user to do with this document? Is it for the CEO? No. Too long. The manufacturing VP? No - still too long and verbose. The cadre of plant managers and production managers? Maybe, but they are apt to be cautious, short ranged in their outlook and frequently sarcastic about such proposals. Staff engineers and planners? Probably they will be the main readers. But many of them are often already sold on more automation and are quite frustrated; like many of the Task B coalition authors. They need ammunition and concrete persuasive date, not taxonomies and logical maps of the interconnectedness of all factory data. They are "out" of the mainstream but to get "in", they, too, need more practical, down-to-earth advice. Professors?

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Yes, sure, many will love to read this. The conceptual neatness is a thing of beauty. It will attract many academics (and heaven help us all!). So the audience and the user is a problem and this needs new attention and a decision, after which the report could be re-edited with a particular audience in mind.

7. One possibly useful approach would be to view the document as a teaching device and review it completely from first page to last with that purpose in mind.

8. What the document is and is not: What the document is is a marvelously and ingeniously conceived set of concepts about factories. The concepts in fact would be as true of a factory in 1883 as in 1983 or the factory of the future. What the document is not is a road map or instruction manual as to how to get there from here, how to bring about change, how to convince the skeptics, how to gain strategic advantage from new technology.

9. The document is a forecast of a certain group's notions of how a factory of the future might be conceived and integrated and operated as a system. I am quite certain, however, that another group, given the same assignment, could and would come up with a quite different forecast of valid and useful concepts for a future, radically changed factory. Why is this so? It is because there is no one ultimate design for a factory - even a very generic and basic one - any more than for an airplane or boat or model city. Newton thought he had one for physics.

10. This is important for it suggests that the process of deriving such a conceptual scheme is as or more important than the end product. You and your team have been through this process and it has undoubtedly been a tremendous learning experience.

But picture now another team or a group of corporate executives, say from TRW or Bendix or Borg-Warner. They are given your product. Not having participated in the process, your product means little to them at first. But to use it is a deductive process, in cognitive language, whereas inventing it was an inductive process. The concepts

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we develop inductively from our own experience have much more meaning to us than those hand-delivered, fully formed concepts developed by others.

All this suggests that the presentation might be more effective if it could take the reader through the process the team went through, rather than delivering it all completed in a finalized, polished form, which invites disbelief, resistance, and the not-invented-here phenomenon.

11. Conceptually and practically, the coalition is on thin ice and in my opinion is probably seriously in error to so consistently directly state and constantly infer the necessity of a tight, closed-loop integration of data handling and processing in the future factory. A different forecast might anticipate many closed-loop systems with more human interfaces. This prediction is supported by the following

    - major, even disastrous problems in starting up and operating (even after three or four years) complex, large, closed-loop information systems in U.S. industry.
    - the direction and pace of factory automation to date.
    - the problems involved with even modestly sized "islands of automation"
    - the limits of the computer in making judgments as compared to their power and efficiency in searching and computation.

12. A further concern in predicting and recommending such a high degree of integration is that of frightening or turning off potential early adaptors by making the investments and risks appear (to practiced decision-makers) very high.

13. The experiences of the Japanese, Germans, Austrians and French support a more evolutionary, gradual, and modest approach to factory automation than that which seems to be advocated in this document. In its presentation, therefore, I wonder whether you might introduce some of this evidence as a way to reassure your readers that step by step evolution is sensible and may lead to more progress and steadier progress than giant leaps.

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14. Similarly the report would be sobered and made more plausible by introducing many more examples of the approaches taken here and abroad and the positive and negative lessons so learned in the process.[1]

B. IMPLEMENTATION

1. Throughout the document it is implied that the factory of the future is a kind of entity that would have very similar characteristics for companies A, B, and C in the same industry. This cannot be correct, for each company will have its own unique competitive position and strategy for competitive success. Factory A, to be a competitive asset for Company A will have to be particularly capable of certain performance criteria which will differ from B and C.

   This inference of sameness creates kind of a never-never land for the implementor who needs to have explained how s/he can meet the needs of their own unique situation. This is probably not hard to fix in the report but it needs fixing.

2. The implementation strategy seems weak in the following respects

   - it lacks examples and case histories
   - it lacks economic data
   - it never answers company concerns about how to afford massive investments in new, fixed costs
   - it does not deal with the new and radically changed cost mix to be expected in the new factory
   - it does not deal explicitly (i.e. with good examples and reassurances) with the business and career risks the new technology seems to offer
   - it implies single solutions to complex questions such as how to organize the future factory
   - it lacks depth in implementation for it stops in many places at offering mere check lists

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1. See Appendix A - Some Preliminary Findings from the author's research on the introduction of new manufacturing technology in the U.S.A.

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3. I wonder whether it might be possible to portray several scenarios as feasible models for moving toward the future factory based on recent company histories. In other words, there is research data available and situations which could now be researched which would begin to offer your readers some advice as to both pitfalls and successful new manufacturing facilities.

4. In particular such case histories would include

   - where, who and how the project got started
   - the conceptual design for what they started out to do
   - how the project was managed
   - how the capital appropriation was descirbed and presented to top management
   - the role of top management
   - action and results

5. The report is weaker than necessary in relating implementation and results to the needs analysis. (The needs analysis, incidentally, is very well done. It represents a real strength of this work.) Here is a big open loop which could be closed by demonstrating just how the future factory might address present needs and falldowns.

6. As the group discussed in Dayton, what is needed is a short statement focusing on "what's really different" about the future factory. In this long and complex and overloaded document, the reader can never get in one place what is to be different in costs, balance sheet, performance, flexibility, service levels, and life in the work force.

7. The Human Resource management section is ok as far as it goes, and, in fact, it is good. But it could be more explicit and draw on the literature of work restructuring so as to offer more concerning the probable impact of the future factory on job content, skills, the QWL, the experiencing of future factory life, changes in the job of the supervisor, plant manager, labor relations, and personnel officers. (See Appendix A.)

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29 June 1984

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8. I expect the major advantages of the new factories to be strategic ones, allowing companies to move faster in new products, offer a greater variety of short runs and customer specials, more consistently outstanding quality, and more rapid delivery. This is touched on in several places but is never made the outstanding emphatic point it should be. In fact, there can be no operational reasons sufficient to justify the enormous investment and risks in the future highly mechanized factory. The payoffs must be in strategic leverage.[1]

Respectfully submitted,

Wickham Skinner

Wickham Skinner

WS/stl

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1. Appendix B is a working paper later published in the Journal of Business Strategy Vol. 3, No. 4, which focuses on the strategic advantages of the new manufacturing technology.

3.6 Comments, Dr. Joseph Harrington, Jr., Arthur D. Little, Inc.

This section contains the letter of comments written by Dr. Joseph Harrington, Jr., concerning the briefing of project 1105 in Dayton, Ohio, on 4-5 May 1983

ICAM PROJECT PRIORITY 1105
ESTABLISHMENT OF THE FACTORY OF THE FUTURE FRAMEWORK

Comments of Joseph Harrington, Jr., Regarding
Meeting of May 4 & 5, 1983 at Dayton, Ohio

In accordance with your request, this set of comments will be addressed to three points:

I An assessment of the documents presented, SD, NAD, and SRD (particularly the latter) and the conduct of the meeting.

II Thoughts on the Conceptual System Specifications.

III Thoughts on Implementation Strategy.

Priority 1105 is an extremely tough assignment; some might consider it an almost impossible task. I am most impressed with the work which has been accomplished to date, and the presentation of the documents. The meeting in which the coalition solicited the advice and comments of a panel of five experts was most effectively organized and run, and elicited good responses. These in turn elicited thoughtful replies from the coalition members and the ICAM office personnel present. All of this bodes well for the remainder of the project. Therefore, what follows is to be taken as constructive detailed comments, which you requested.

I ASSESSMENT OF THE DOCUMENTS AND THE MEETING

The first document issued in this project was the Scoring Document, which almost immediately presents the FOF / A0 Diagram and the corresponding Node Diagram. Ray Neal asked specifically if we thought that the team had acted too quickly in setting in position the six functional boxes.

I tend to think that present day organizations and present day concepts of the AS IS functions did cast a strong shadow on this structure. It was modified as the project proceeded, but I see the structure a little differently, particularly as my train of thought is predicated on a generic "manufacturing" environment rather than an aerospace environment selling principally to the Government.

I feel we should first carefully define "Factory", a word which is widely used for many different scopes of activity. In the NAD the term is defined, but I fear that the definition itself may predispose the concept which is to be generated. I prefer the term "Enterprise", a concept neatly defined at the top of page A-4 of the NAD. Following this line of thought, I see four major divisions of an enterprise; if they were function boxes we would label them: Manage, Manufacture, Market, and Support (Support the enterprise, such as with financial, legal, personnel, and data processing services). In turn, "Manufacture" would have four major divisions: Manage Manufacturing, Develop Products, Produce Products, and Support Products in the Field. Similarly, "Market" would have six major divisions: Manage Marketing, Assess Needs of Marketplace, Establish Marketing Policies, Advetise Products, Sell Products, Service Products in the Field. I attach a node diagram from my new book which shows this structure, purely for illustrative purposes.

It is obvious why I find the structure shown in the A0 diagram to carry too much flavor of today's aerospace factory structure. SAD Figure I-4 is a similar node diagram, but it places management of the enterprise on a par with "Provide Resources", "Provide Logistic Support", etc. I feel it should have a senior status to these functions. Also, the A1 node "Provide Customer Liaison and Services" is really only a portion of the Marketing function, while another portion of customer services is over under Node A61 "Provide Field Service". Both deal with relations with the user, external to the enterprise, whereas the other functions are internal to the enterprise.

To answer Ray Neal's question, then, I think that there was too early a move in selecting these six major boxes. However, the coalition had to start somewhere, and it is quite understandable that they started with this structure. It is not as irrevocable a posture as it might be, and I think that later thinking, as evidenced by later documents, shows less of its influence. What ultimately emerged as the main structure of this project are the seven needs categories, and the systems requirements arising out of them. When these are applied to the manufacturing structure, the conceptual framework of the Factory of the Future will emerge.

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The Systems Requirement Document is an impressive piece of taxonomy. It is very thorough -- perhaps too thorough, as its very size will preclude a proper study by many people. It should have a summary statement of perhaps a tenth of the size IN ADDITION to the entire document, and in a separate binder.

The key emphasis is on the Information Resource Management subject, as is proper. That section of the document (Section 3) is an excellent exposition of the subject. I have no suggestions for changes in this section.

Similarly, second emphasis is placed on Management of the Factory of the Future, Section 4. Again, this section shows excellent thinking, although it could stand some simplification, and perhaps some clarification with examples. It focuses on the scheduling and orchestration of a tremendously complex structure, a real challenge to the FoF conceptual plan. We all seemed to agree that with IRM in place, this task would be much easier. As may be seen from my remarks above, I see this function as senior at all levels to the functions being managed on that level.

The third priority need is the Product Definition and Planning Section, Section 5. Section 5 as amended is practically a textbook by itself. This is where the coalition has departed most radically from the AS IS factory structure and thinking, and where the greatest exposition and selling effort will be required. Because it is such a large subject, simplification wherever possible is essential.

I concur with Buffum and Lardner that there is a legitimate division line between Product Definition and Production Planning. Although the process is iterative, and moves back and forth across this line, there is still reason to keep a functional distinction between the two. True, CAD/CAM, Group Technology, and Generative Planning are employed in both areas, and serve to tie them together. But there are good management reasons to have them separated: Management may decide, having seen a detailed design and a model demonstration of a new product, not to go ahead with its production. Or management may elect to have two sources of supply, equipped with different facilities; this would require that the melding of the concerns of product definition and production methods be done twice, and separately. I also feel that there is a very close tie between Production Planning and Production. During the course of the product's life cycle conditions may require many adjustments between these two which do not affect the Product Definition.

However, there is a much closer tie between product definition and production planning than now exists in many establishments. The conceptual design will have to wrestle with this problem.

Product Assurance is treated in Section 6. We did not get too much discussion, if any, of this section, but I feel it misses the mark rather badly. This may be because of the overhanging influence of MIL-Q-9858A Sect. 6.1. Product assurance is normally achieved in two manners: Quality Assurance, and Quality Control. The latter is the main theme of Section 6 -- how to inspect the product. It is an old truism that you cannot inspect quality into a product; the best you can do is to cull out inferior pieces. One must inspect, as the MIL spec insists, but one must also address the problem of designing the product and the production methods so as to increase the incidence of good product. In other words, make it right the first time. I found very little of this thesis in Section 6, and I think the project would be criticized if the document got out without a balanced treatment.

The remaining needs priorities -- Human Resource Management, Materials Management, and Financial Management were considered to be well done. We should emphasize integration of the humans just as we do integration of the information systems into the ultimate Computer Integrated Manufacturing system.

We did not see the State of the Art document, hearing instead an outline of its contents. Considering that we are going to be working with technologies ten years ahead, and possibly not yet conceived, I would not waste too much more time on today's State of the Art, even if it is Leading Edge technology. The importance of technology as a factor in the Factory of the Future scarcely needs reiteration.

II THOUGHTS ON THE CONCEPTUAL SYSTEMS SPECIFICATIONS

As I understand this part of the task, an architectural framework is to be conceived and set forth outlining the best considered opinion as to what a manufacturing enterprise should be like in the 1990 - 1995 time frame. As Lardner pointed out, just setting it forth will hasten its arrival. This can only be an idealized architecture; every enterprise will have a different actual architecture. It must therefore be complete enough so that it will encompass any necessary variants -- i.e., a generic architecture. And it is not to be designed in this task, but only to have its characteristics specified.

The Factory of the Future will be achieved from the Factory of Today by a slow, evolutionary process. There is a tremendous inertia in the existing manufacturing establishment, in the facilities, capital equipment, technology, tooling, personnel, and management. It will be changed incrementally, as it has been changing over the past two centuries and is changing today. This project is merely to set forth a clear and acceptable target.

I agree that the FOF will incorporate all of the functions of the FOT. It is the embodiement of the technology that will continue changing, and this includes the management, information handling, and material conversion technologies. We call the change mechanisms automation and computerization. Let me repeat my analogy of the jig-saw puzzle.

My grandson was assembling a jig-saw puzzle one day when one of the pieces accidentally fell to the floor, and the dog ate it. I had to make a replacement piece which, while lacking the picture element on its surface, had to fit precisely into the space between the adjacent pieces; no overlaps and no gaps. I refected that this is what we do when we automate or computerize some manufacturing function. While we may have improved the function, it must fit into the existing organizational pattern. We do not change the inherited crazy-quilt pattern of the system.

This traditional architecture of manufacturing and the organizations that go with it were created for good reasons. When manufacturing was accomplished by human digital skills and human mental skills, organizational structures were tailored to fit the available humans and their skills. But with the steady trend to the transfer of skills to mechanical and data processing devices, we need a new and better rationale for structuring manufacturing. It is to be found in the functional steps inherent in the science of converting raw materials into desired end products. Describing this structure is the essence of the systems specification task. It is complicatd by the fact that the FOF in the time frame specified for the Systems Specification document may deal with products, facilities, and personnel not now known. This is what the mathematicians call "A highly non-trivial task!".

In view of the fact that the project is aimed at the 1990 - 1995 time frame, I suggest that the Project Team focus on what may reasonably be accomplished. I liked Lardner's concept of the computer being applied principally to structured decisions, and used only as an assist in semi-structured decision making. I suggest that the specifications take note of the strong influence of certain factors which, although they fall outside the assignment of the Project, must still be taken into consideration. These include geopolitics, sociological changes, availability of materials and energy, and economic conditions in general. This was mentioned in NAD at Section 3.4.

I suggest that the Project keep in mind the nature of the end product of this task. It is not a turnkey plant, not hardware or software, not an organization chart, not a set of standards, but a concept It cannot be made mandatory. This must also be kept in mind by those to whom the end product is proffered. I liked Skinner's description of the end product as a credible model of how the world will be.

III THOUGHTS ON IMPLEMENTATION STRATEGY

Implementation in the case of this project means diffusion of the credible concept to industry, and a reasonable level of acceptance by the early adopters.

I suggest that the credible model of how the world will be is all that need be released. How the project team got to it is not important and may open up a field of debate better left closed.

The first step will be the preparation of the model in some compact form and its presentation at some function such as Industry Days. You may e pect that it will be received with either polite interest or complete indifference. Such things take time for assimilation -- months or even years before their true value is appreciated. Simple documents should be available for anyone interested.

The second step is selling the concept to those who may reasonably be expected to understand, accept, and implement it. This is a job for a technology transfer specialist, and with all due respect for the manifest skills of the project team, they may not have the special promotional skills necessary. Fortunately, this project as a part of the ICAM Project does not have as its target the whole of Industry, but - at least at first - only the aerospace industry. This is a reasonably reachable target.

The National Academy of Engineering Committee on Computer Aided Manufacturing conducted a study on technology transfer in connection with the earlier ICAM work. We learned that new technologies arise in a very small sector of an industry, called the "innovators". The first diffusion of the new technology is to a group of about 10% of the industry known as the "early adopters". These companies will try an idea without an iron clad demonstration of economic justification. These are the people to whom the technology transfer specialists turn their first attention. (Later, a large chunk of industry will adopt the new technology, having seen it demonstrated in practice and its economic justification proven. By then the technology has been more or less standardized, and the reward for its adoption has shrunk to a narrower margin. The rest of the industry will be forced into adoption by sheer weight of competition.)

This means that Project 1105 can still further narrow its technology transfer program to a relatively small number of aerospace companies. Once they adopt the concept, the rest will follow in self defence if nothing else, and the doctrine will spread to other industries as well. Therefore, implementation narrows down to presenting the concept to half a dozen key corporations, a not insurmountable task.

As a consultant who has done such jobs many times in the past, I can testify to the most effective procedure for this presentation effort. A small group - possibly two men - should meet with the Chief Executive Officer of the target corporation, and one or two of his associates. The reason for approaching the CEO is that this concept has an impact on the total enterprise, and can not be "bought" by anyone other than the person whose responsibility and authority spans the whole enterprise. The reason for the "one on one" approach is that the CEO is free to listen and ask questions, to discuss possible implications for his company, and to argue points without committing himself in front of his entire organization. He may later ask for a presentation to a larger group of his people, or to several groups.

I would not try to make a moving picture for a visual aid for the 1105 Project. This is just not the sort of subject matter that lends itself to the slick, uninterruptible, music-in-the-background movie medium. What is needed is a sizeable number of slides, from which a few can be selected, carefully chosen for the specific company and man to be addressed. The presentation is tailored to the enterprise. Slide presentations can be halted for discussion, backed up to clarify a point, changed on the spot to react to the listener's reactions, and extended or abbreviated as seems best. And they are much less expensive than movies.

The CEO may ask what the costs and risks will be. In this type of concept, there is no way to answer that question; it will have to be worked out for that specific user. In any event, the acceptance of this concept is not an economic exercise, but a strategic decision. The CEO will next consider what the concept will do to his organization and to the skills of his employees. This is probably the most important part of the transfer of the concept, and is where the flexible slide show media comes into its own. What the CEO will not ask, but will wonder about, is what the concept will do to or for him, personally. He must be made the "champion" for the concept in his company.

When the technology transfer team has contacted the "early adopter" types of CEOs in the aerospace field, much of the implementation task will have been accomplished. More work would yield a diminishing return in the early stages of the transfer, and in the later stages it will simply be a matter of presentations as often as opportunity presents itself.

SUMMARY

Project 1105 is to be commended for good work on a very difficult assignment. The end result of the Project's effort will be a set of specifications for a credible model of how the world will be in 1990 - 1995. The transfer of this concept to industry will require an unusual approach, but fortunately may be directed in the first instance to a relatively small number of probable early adopters.

Joseph Harrington Jr.
Joseph Harrington, Jr.
May 10, 1983

3.7 <u>Comments, Richard E. Spears, Boeing Computer Services</u>

This section contains the letter of comments written by Richard Spears concerning the briefing of project 1105 in Dayton, Ohio, on 4-5 May 1983.

BCS Boeing Computer Services Company
A Division of The Boeing Company

3801 South Oliver, Wichita, Kansas 67210

May 20, 1983

Richard R. Preston, Captain USAF
Project Manager
Computer Integrated Manufacturing Branch
Manufacturing Technology Division
AFWAL/MLTC, Bldg. 653, Room 224
Wright Patterson AFB, Ohio 45433

Don Norwood
ICAM Program Manager
Vought Corporation
P. O. Box 225907
Dallas, Texas 75265
Mail Drop 2-A5
Unit 2-20150

Gentlemen:

Attached you will find the report that you requested me to prepare as a result of the Dayton meeting May 4th and 5th on Factory of the Future Concepts.

I would like to thank you for your hospitality and appreciated the opportunity to participate in your review.

Sincerely,

R. E. Spears
Boeing Computer Services

GENERAL IMPRESSIONS

NEEDS ANALYSIS DOCUMENT

In general I find the documents to be very good. I believe the Needs Analysis Document did an excellent job of categorizing manufacturing needs so that proper attention could be given to the seven issues identified. If you had tried to address solutions to the numerous detail needs of a factory, you probably would not have been as successful as you are going to be by categorizing. The document treated the subject of Information Resource Management very well. I believe that it is very important that Information Resource Management is properly addressed in the Factory of the Future Framework. I am sure that if companies do not understand Information Resource Management philosophy and mechanization, they will not be able to obtain the productivity improvements that the Air Force is striving to achieve.

STATE-OF-THE-ART DOCUMENT

This document did a pretty good job of identifying network capabilities, software tools, and database managers that are on the market today. Although much of the information in the document is generic in nature, it is fairly obvious that the packages identified in this document are only state-of-the-art on the day that the document is written. I don't know how you intend to keep a document of this type updated. It may be that a company that embarks on modernizing its manufacturing data systems must make a similar study of available tools prior to investing their money.

The subject document addresses the seven requirements areas in reasonable detail. I believe that it is entirely reasonable that an aerospace company could take this document, digest it, and implement a system that would improve their productivity.

The issue that was not discussed at great length in the document, though, is how would they implement these concepts and address the subject issues without an implementation plan that leads them through a transition from their present systems into state-of-the-art systems. System flow charts could be developed that show the relationship between existing systems and any systems that would have to be developed to support the factory of the future framework. This would also allow a company to utilize data systems that have been developed by the Air Force to assist them in implementing factory of the future tasks. If possible, you should try to include examples of how a company could do this. For instance, you may want to use the flow chart technique generated by Boeing on the Integrated Sheet Metal Contract.

I believe a transition can be made from existing data systems to state-of-the-art data systems fairly easily if strategic data planning is accomplished. This allows you to build a plan where all future data systems developments are accomplished under the umbrella of the Information Resource Manager. A data dictionary can be developed that supports both the new and the old systems.

The question that an aerospace company will have to answer is how many of the ICAM produced data systems can be incorporated into that company's existing data systems in an economical way. Aerospace companies should find the use of the ICAM data systems cost effective because it is extremely expensive and time consuming to rebuild existing data systems. If they can assure themselves that the use of the ICAM systems will not compromise their organizational and management philosophies, they will find the use of the ICAM data systems more attractive. If they exercise the option of adapting their management philosophy to the ICAM philosophy, they will be able to use more of the ICAM data systems than if they try to install the ICAM data systems in the face of conflicting management philosophies.

The inclusion of proposed organizational charts should be considered. This consideration will help the industry to understand that the functional organization in the FOF Document are not defacto proposed organizational charts.

It will be reasonable to expect that a company could rebuild its systems at a cost much lower than systems have traditionally cost if life cycle software packages are developed. It is not clear to me, however, that a single life cycle software system will satisfy the requirements for embedded software, business and scientific. If the software industry is faced with the problem of providing a separate life cylce system for each of these areas, the target date when all three would be available will be extended.

3.8 Comments, Harvey E. Buffum, H. E. Buffum Company

This section contains the letter of comments written by Harvey Buffum concerning the briefing of project 1105 in Dayton, Ohio, on 4-5 May 1983.

H.E. BUFFUM CO.
PRODUCTIVITY IMPROVEMENT

17 May 1983

Robert L. Moraski,
FOF Project Manager
Vought Corporation

Dear Mr. Moraski:

I would like to complement you on the overall quality of the work that your team has done on the Factory of the Future project. There is a lot of information that will be of significant value to the industry.

In Attachment "A," I have included a summary of the comments that I made at the meeting in Dayton. In general, I would recommend that the documents be made more systems definitive and less philosophical. I believe that you will be doing some revising of the documents, so I will not try to be specific with sentences that would go into your revision of the document, but instead provide you information so that you can change the documentation as your editor fits it together.

Attachment "B" is the invoice for expenses and changes for the services rendered.

I would like to express my appreciation for the opportunity of working with your team. I am looking forward to reviewing the results of your document revision and the meeting in August. Please call me if you have any questions.

Sincerely,

Harvey E. Buffum

Enclosures: Attachments A and B

ATTACHMENT "A"

Summary of H.E. Buffum Comments
Made at Dayton Meeting, May 4 and 5, 1983

1. Management Exposure to Documents

It is very important that top manufacturing management in the aerospace companies have an understanding of the systems that will be required in the Factory of the Future (FOF) for the 1995 time period. These systems have the potential for significantly reducing production costs and improving quality. With a good management understanding of the potential benefits, better support will be provided to systems development effort required to meet future objectives.

It will be very difficult for a manufacturing vice president or director to find time to read and study these documents because of the detail and length of the documentation. I believe the best way to convey the information is a one-on-one presentation made by his technical staff person who has a good understanding of this documentation and their present systems.

Many of these top people have had a limited exposure to the needs and potential benefits of the integrated computer-aided manufacturing systems noted in these documents. It is best if they can ask their questions freely without concern for their possible lack of exposure to computer-integrated systems.

I would propose that the contractor be authorized to prepare a slide presentation and supporting documentation that can be used in the aerospace companies to inform the executive manufacturing management of the finding of this contract relative to the Factory of the Future. This slide presentation would be presented by key company manufacturing technical staff when they are adequately knowledgeable of this program, or a knowledgeable industry representative, when required. When possible, it would be best to use staff from inside the company because this provides a foundation for the in-house staff that will have to be involved in the development and implementation work. In some cases, the company representatives that served on the coalition effort under Mr. D.L. Norwood's direction could bring this story to the appropriate management.

When the companies lack the internal staff, outside consultants could be used to convey the message.

2. Configuration Control

As the transition is made from the predominantly metalic primary structures of today to the composite structure of the future, configuration control will become increasingly more critical. Even today, some companies have lost configuration control because of the number of subcontractors and the difficulty of keeping records on the large numbers of parts and assemblies in process.

In the commercial airplane business, it is very important that the manufacturer have the capabilities of configuring the airplane, its power plants, systems, and interiors to suit each customer's need. With problems of sales, financing, and changes in customer's need, one major producer finds it necessary to have from 15 to 20 master schedule changes per year that requires significant resequencing of airplanes, major components, and systems.

The records for each individual airplane must be maintained for the life of the vehicle in commercial use. It is necessary because of government regulations and customer need that the structural detail of each airplane's configuration information be readily available. For example, when any one of the commercial airplanes makes a crash landing, the manufacturer must be able to tell the customer the exact status of detail parts or assembly for that particular airplane in very few hours. The parts will often be kitted with the tool fasteners and planning for shipment to locations all over the world for field installation to get the airplane back in the air in the shortest possible time.

Military systems currently have many of the same configuration control problems but with a little less emphasis on a variety of customers but with more sophisticated systems.

The composites structure of the future will require a great deal of quality and configuration control data in comparison to that normally required for metalic structures of today. To provide a view of these special requirements, I will briefly outline some of the critical steps that currently appear to be a requirement for future critical composite structures. As the technology advances, the needs will change but it appears unlikely that the data requirements will be drastically reduced.

Typical Data Required for Critical Composite Structures

A. Chemical Characterization of Materials

Incoming batches of material will be analyzed with sophisticated computer controlled equipment so that the chemical characteristics can be compared with the producibility and performance history of every part that uses any part of that batch of material. The objective is to be able to eliminate undesirable material before it is ever processed in the Factory of the Future, and to insure that there are ways of correlating failures to their causes. This type of data will become a part of the data for each part and assembly.

B. Part Configuration Control

Each ply of resin-impregnated fabric, when fabric is used, would be defined by a computer compatable data set used by both engineering and manufacturing. It is most likely that the material would be trimmed to its configuration using computer controlled machines working directly from the engineering data sets. The data on the configuration and batch of material would become a part of the computerized data base.

C. Assembly Configuration Control

As each ply of material is automatically placed in position, sensing equipment would verify that the proper configuration of ply was placed in the proper position. This data would then end up as a part of the computerized data for the configuration of the assembly.

D. Cure Cycle Recording

There will be many cure options available with variations in temperature, pressure, time, and energy sources. These cycles will become a critical part of the computerized quality records.

E. Assembly Inspection

Each of the steps taken in A through D are directed at insuring that a high-quality assembly is produced, and that in those cases where a failure has occurred, there will be a data track that will lead to an understanding of where the true problem is. The next step in the quality assurance process is that of using computerized inspection techniques, such as computerized through transmission ultrasonic inspection systems to detect voids of imperfections in the completed assemblies.

F. Assembly Usage

The final step in the records of a specific assembly is its assignment to a specific customer's airplane and the storage for retrieval for the service life of the airplane.

The configuration control problems on some major systems development efforts have caused some very large cost overruns and schedule delays. It is recommended that a strong thread of configuration control be woven into the documents for the Factory of the Future. Without this important function planned into the systems development effort, there is no assurance that the systems will support the required product quality and reliability.

3. Redefinition of Executive Responsibility

In 5.3.4 of the System Requirements Document, it was stated that there should be a single executive responsible for a combination of some design and some manufacturing functions. I believe that this recommendation is inappropriate in this document for two reasons:

a. System Requirements Document does not appear to be the appropriate place to define management reporting relationships.

b. Some companies have found it to be very affective to have teams of manufacturing and quality people assigned to the engineering design areas to aid in the evolution of the optimum designs. These operations representatives sign the drawings for the manufacturing and quality management that has the actual production responsibility.

4. Human Resource Management

Page 7-7, the third paragraph from the top has a "Diagram 2" reference that I assume should have been Figure 7-4.

In this same section are noted "Human Resources Management" functions, such as Payroll Personnel Systems (PPS), Employee Records Systems (ERS), etc. With the continuing introduction of new chemicals into the work place, I believe that serious consideration should be given to including an "Epidemilogical Data Base" in the computerized personnel data.

The epidemilogical data base would keep track of all of the hazardous materials that enter the factory, where they are used, who was exposed to them under what conditions, for how long, and the appropriate medical history of the individuals.

Most aerospace companies tend to have very poor records of the hazardous materials that they use, and even less information on the exposure of individuals. The big problem today is to try and determine what should be considered hazardous. The present situation is clouded, but with the emphasis being placed on the handling of hazardous and toxic material, I believe that a 1995 HRM System would be incomplete without this provision.

I would suggest that you call Mr. Michael Stewart, Boeing Commercial Airplane Company Organization 6-5645, phone (206) 237-6467 for information on a computerized epidemilogical data base that is probably the most advanced in the aerospace industry today.

5. Response to Questions Asked by Project Management

A. Who should be responsible for information resource management?

ANSWER - The information resources of a company are one of its most valuable assets. Responsibility should be at the executive level where engineering and manufacturing both report. In some companies, this is at the level of the executive vice president where several divisions of the company report that use the same data base.

In distributed systems, the functional organizations need to be able to use the data as they wish.

B. What should we say in future systems specifications?

ANSWER - I believe that each detail system specification document prepared for the use of an aerospace company will be different. There will be similarities in the type of data used and where it is used.

To get a handle on the problem, I would ground rule a typical company of modest size and limited product mix, and prepare a specification. Your consortium members should be able to provide data usage information that could be factors for the company size that you select. The resulting data then could be used by many companies to develop their own specifications. This known foundation would be a much better starting point for most companies than having no starting point.

C. How should the balance of the work be prioritized?

ANSWER -

1. Revise existing documents as recommended.
2. Prepare what could be considered to be an abbreviated system specification with a lot of back-up data in the appendix.
3. Develop an implementation plan.
4. Develop special presentations that can be used to communicate the results of projects to industry.

D. What should be the strategy for implementation?

ANSWER - A systems development plan can only be implemented by a company that is convinced that it will get a return on its investment or must take action to remain competitive. I am of the opinion that some of the new weapons systems will force the introduction of more computerized systems. There needs to be more emphasis on production capability in the source selection process than there has been in the past.

The ICAM program is taking the steps that are required in evolving the building block for the Factory of the Future. By working on these building blocks or modules, they are, through the competition process, getting many companies headed in the right direction. By giving a development contract to one, they are stimulating many to try and stay competitive.

3.9 Project 1105 Overview and Factory of the Future Scope (presentation)

This section contains the project overview presentation given by D. L. Norwood

CONCEPTUAL DESIGN
FOR
COMPUTER INTEGRATED
MANUFACTURING

A-46

CONTRACT NO. F33615-81-R-5119
AFWAL/MLTC PROJECT NO. 1105

D.L. NORWOOD - PROJECT MANAGER

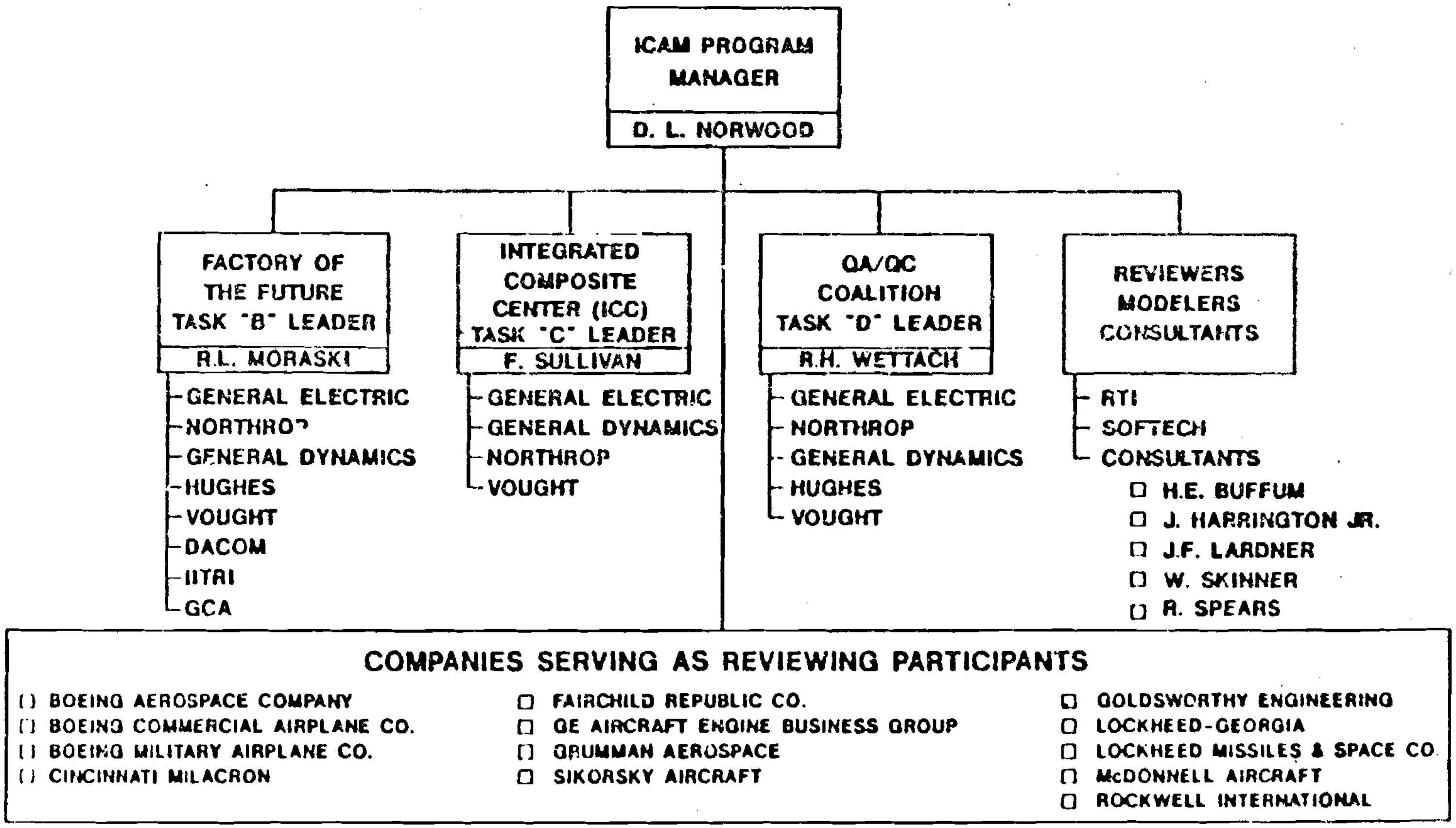
VOUGHT
CORPORATION

FTR110510000U
29 June 1984

P1-2746-10

PROJECT PRIORITY 1105 ORGANIZATIONAL CHART

VOUGHT



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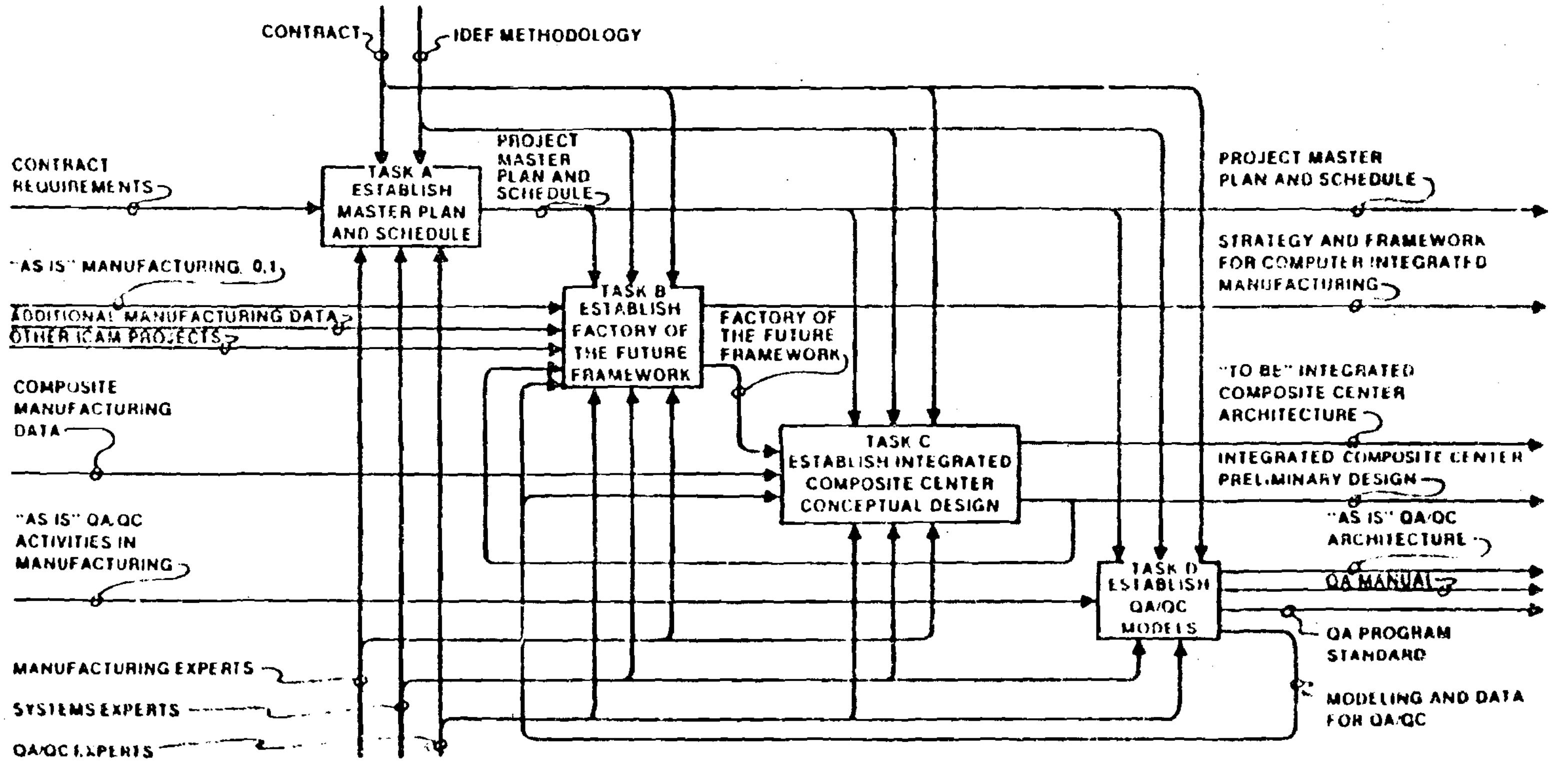
FTR110510000U
29 June 1984

CONCEPTUAL DESIGN FOR COMPUTER-INTEGRATED MANUFACTURING



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VOUGHT

TECHNICAL REQUIREMENTS/TASKS

The following tasks shall be accomplished:

Task A - Establishment of the Master Plan and Schedule (paragraph 4.1).

Task B - Establishment of the Factory of the Future Conceptual Framework (paragraph 4.2). (Option 1)

Task C - Establishment of the Integrated Composites Center Requirements Definition and Conceptual Design (paragraph 4.3).

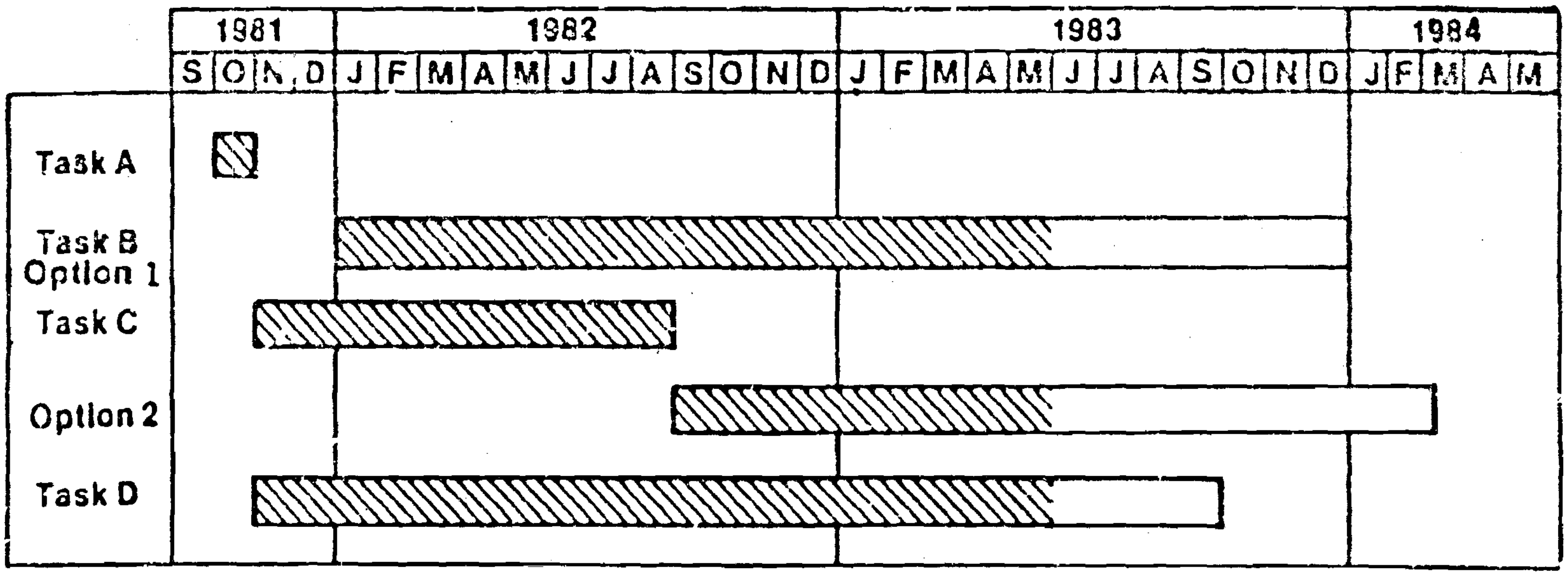
Option 2 - Establishment of the Integrated Composites Center Preliminary Design and System Specification Document (paragraph 4.3.8).

Task D - Establishment of the "AS IS" Architecture of QA/QC Functions (paragraph 4.4.2), establishment of the ICAM Quality Assurance Manual (paragraph 4.4.3) and a Product Assurance Program Standard (paragraph 4.4.4).

P3-630-1

VOUGHT

TIME SPAN



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29 June 1984

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TASK B ORGANIZATION CHART

TASK "B" LEADER VOUGHT
R L. MORASKI

VOUGHT TEAM — R L. MORASKI
- D L. NORWOOD
- S J KELLY
- R K NEAL
- A H SAUNDERS
- A REINGOLD

NORTHROP TEAM — L O WARD
- F E SULLIVAN
- B E ROBERSON
- P BAUER
- T CERMAK

GENERAL ELECTRIC TEAM — R H WATTACH
- J W DRAFFEN
- B R SHEPHERD
- W P. VINSON
- A S RUBENSTEIN

GENERAL DYNAMICS TEAM — J P WATKINS
- P COX

HUGHES AND GCA TEAM — F GOOD
- S. SIMIK
- W. JORDAN
- D SHUNK

DACOM TEAM — A W SNODGRASS
- B N SNODGRASS
- W A HUSKEY
- B R DAVIS
- D S APPLETON
- C MARTIN

IITRI TEAM — DR J CHURCH
- J M JACOBIUS
- R DIESSLIN

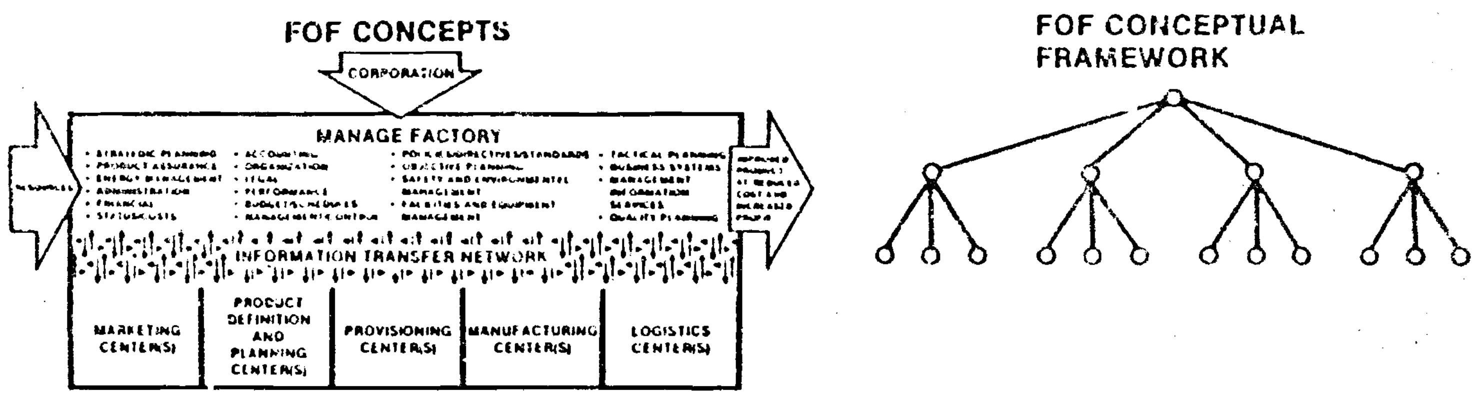
REVIEWERS MODELERS CONSULTANTS
- RTI (J TURNER)
- SOFTECH (M DAVIES)
- CONSULTANTS
  - H E BUFFUM
  - J HARRINGTON JR
  - J F LARDNER
  - W SKINNER
  - R SPEARS

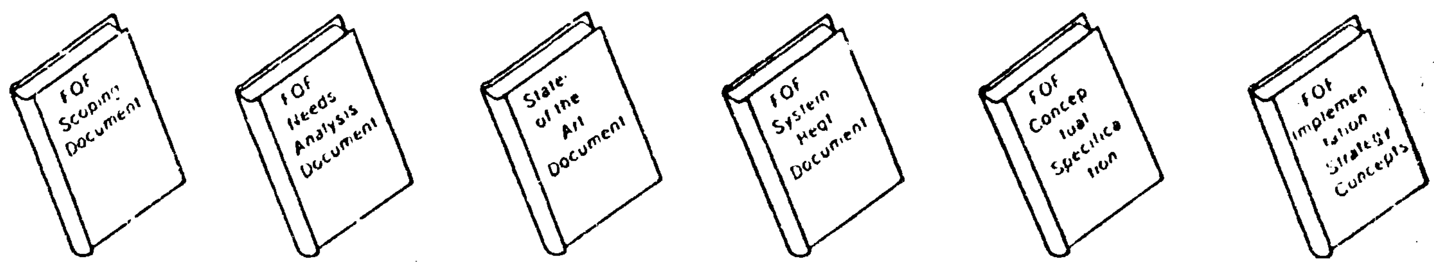
COMPANIES SERVING AS REVIEWING PARTICIPANTS

- BOEING AEROSPACE COMPANY
- BOEING COMMERCIAL AIRPLANE CO
- BOEING MILITARY AIRPLANE CO.
- CINCINNATI MILACRON
- FAIRCHILD REPUBLIC CO
- GE AIRCRAFT ENGINE BUSINESS GROUP
- GOLDSWORTHY ENGINEERING
- GRUMMAN AEROSPACE
- LOCKHEED GEORGIA
- LOCKHEED MISSILES AND SPACE CO
- McDONNELL AIRCRAFT
- ROCKWELL INTERNATIONAL
- SIKORSKY AIRCRAFT

P3 1627-11

TASK B - Establishment of the factory of the future conceptual framework





FOF Scoping Document

FOF Needs Analyses Document

State-of-the-Art Document

FOF System Requirements Document

FOF Conceptual System Specification

FOF Implementation Strategy Concepts

P3 1206-1A

TASK B MILESTONES

PROGRAM MILESTONES	START DATE	COMPLETION DATE TARGET	COMPLETION DATE ACTUAL
4 2 ESTABLISH FOF CONCEPTUAL FRAMEWORK	15 JAN 82	31 DEC 83	
4 2.1 SCOPE TECHNICAL EFFORT AND IDENTIFY NEEDS	15 JAN 82	30 JUL 82	10 FEB 83
4 2 1.1 SCOPE TECHNICAL EFFORT	22 JAN 82	30 MAR 82	30 MAR 82
4 2 1 2 IDENTIFY NEEDS	8 APR 82	30 JUL 82	4 AUG 82
4 2 2 ESTABLISH IMPROVEMENT CONCEPTS	15 MAY 82	3 MAR 83	23 MAR 83
4 2 2 1 EVALUATE IMPROVEMENT CONCEPTS FROM EXISTING SYSTEMS EFFORTS	15 MAY 82	3 NOV 82	3 NOV 82
4 2 2 2 STATE OF THE ART INVESTIGATION	15 MAY 82	30 SEP 82	5 OCT 82
4 2 2 3 DOCUMENT SYSTEM REQUIREMENTS	19 JUL 82	3 Mar 83	23 MAR 83
4 2 3 DETAIL FOF CONCEPTS	1 DEC 82	30 SEP 83	
4 2 3 1 ESTABLISH FOF CONCEPTUAL FRAMEWORK SYSTEM SPECIFICATION	1 DEC 82	30 SEP 83	
4 2 3 2 ESTABLISH FOF CONCEPTUAL FRAMEWORK	1 DEC 82	29 JUL 83	
4 2 3 3 ANALYZE FOF CONCEPTUAL FRAMEWORK, CENTERS, AND SUBSYSTEMS FOR INTERACTION	4 JAN 83	22 AUG 83	
4 2 3 4 ECONOMIC BENEFITS ANALYSIS	4 JAN 83	30 SEP 83	
4 2 4 SUMMARIZE FACTORY OF THE FUTURE RESULTS	5 JUL 83	31 DEC 83	
IMPLEMENTATION STRATEGY DOCUMENT	8 AUG 83	31 OCT 83	
FINAL TECHNICAL REPORT	3 SEP 83	31 OCT 83	

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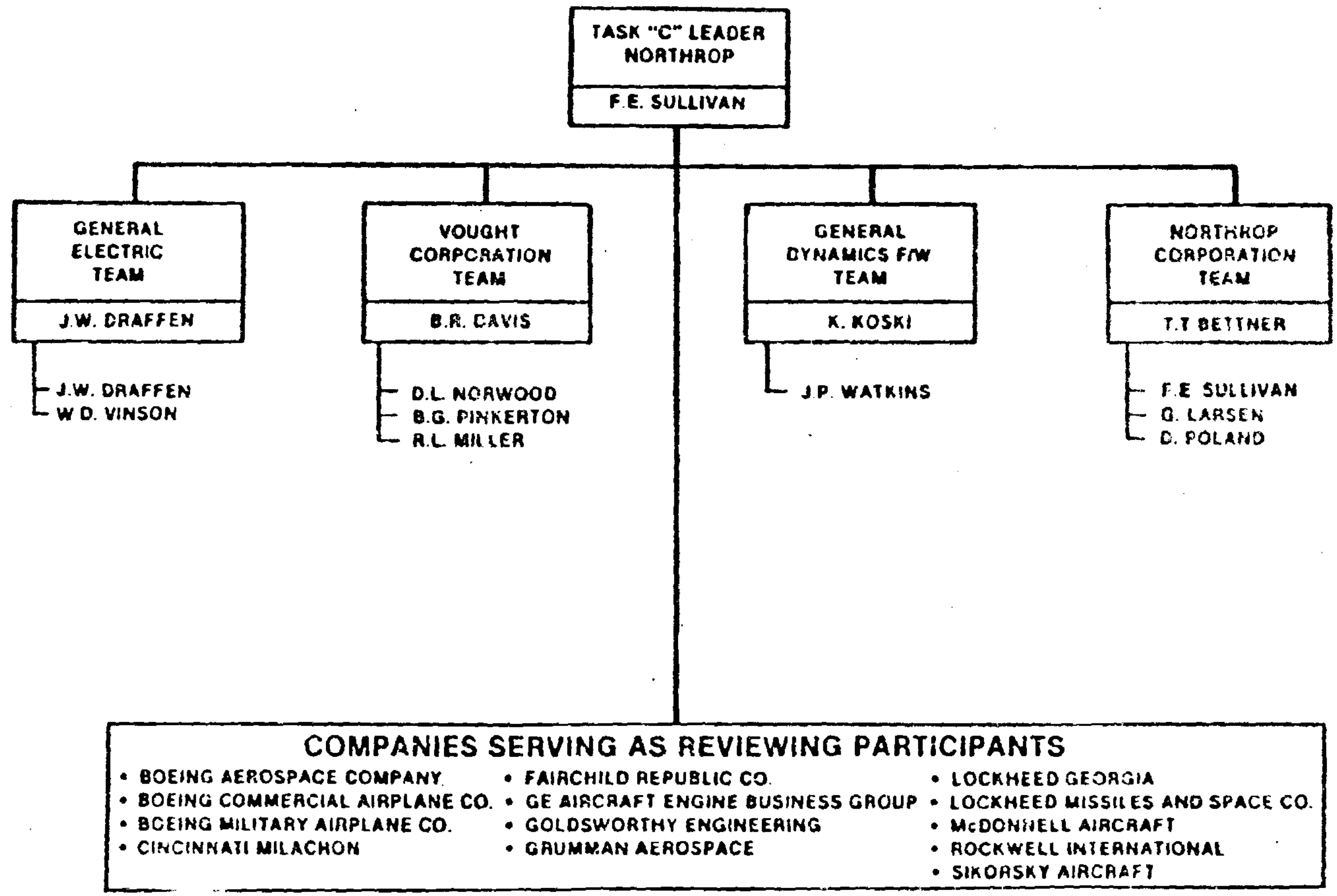
TASK C ORGANIZATION CHART



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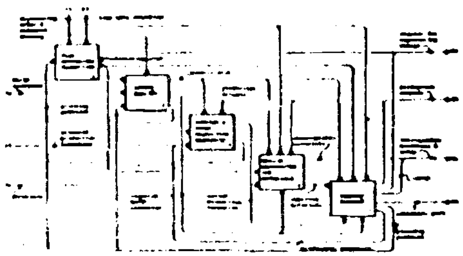
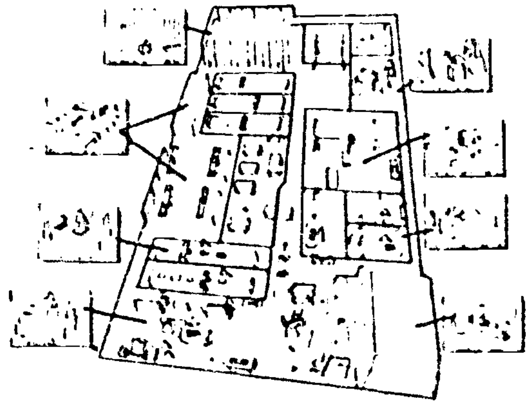
29 June 1984

TASK C – Establishment of the integrated composites center (ICC) requirements, conceptual and preliminary design and system specification

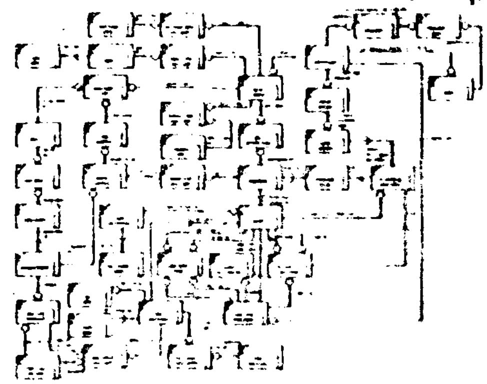
ICC FUNCTION MODEL (ICC_0)

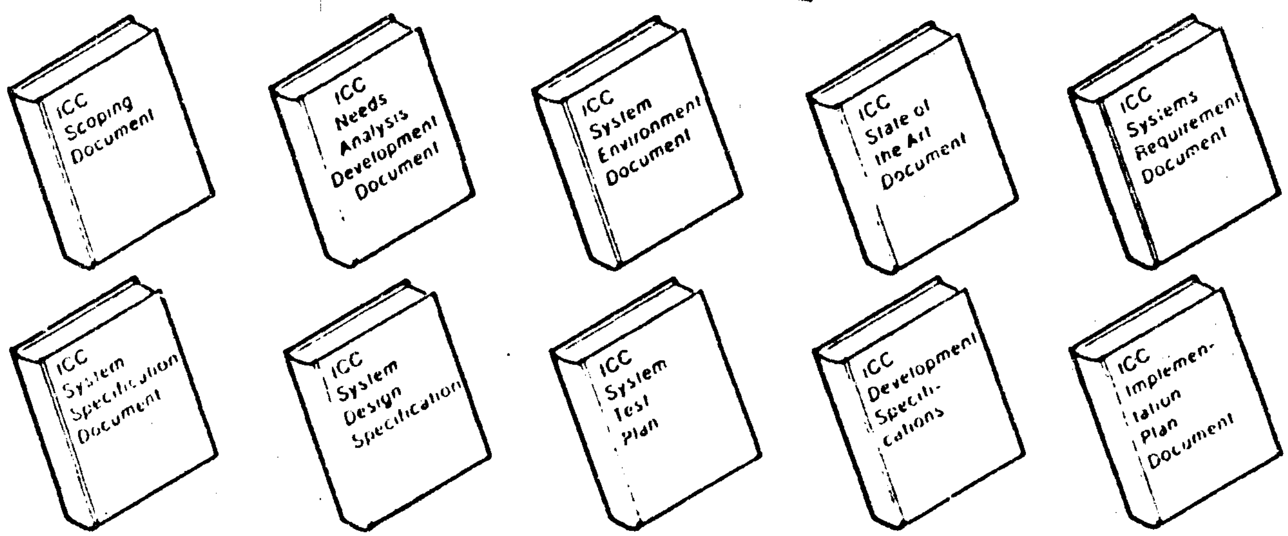


ICC CONCEPTUAL DESIGN



ICC INFORMATION MODEL (ICC_1)





TASK C MILESTONES

PROGRAM MILESTONES	START DATE	COMPLETION DATE TARGET	COMPLETION DATE ACTUAL
4 3 ESTABLISH ICC CONCEPTUAL DESIGN	1 NOV 81	31 JUL 82	31 JUL 82
4 3 1 ESTABLISH ICC SCOPE	1 NOV 81	31 JAN 82	31 JAN 82
4 3 2 COMPLETE NEEDS ANALYSIS	31 JAN 82	30 APR 82	30 APR 82
4 3 3 COMPLETE CURRENT PRACTICE UNDERSTANDING	31 JAN 82	31 May 82	31 MAY 82
4 3 4 FORMULATE IMPROVEMENT CONCEPTS	30 APR 82	30 JUN 82	30 JUN 82
4 3 5 DEFINE ICC SYSTEM CONCEPTS	30 APR 82	30 JUN 82	30 JUN 82
4 3 6 PRODUCT "TO BE" ICC REQUIREMENTS DOCUMENTS	30 APR 82	31 JUL 82	31 JUL 82
4 3 7 UPDATE PRELIMINARY DESIGN SUBPLAN	31 JUL 82	31 JUL 82	31 JUL 82
PHASE III OPTION 2			
4 3 8 PRODUCE PRELIMINARY DESIGN	1 SEP 82	28 FEB 84	
4 3 8 1 REFINE AND DETAIL REQUIREMENTS	1 SEP 82	30 NOV 82	30 NOV 82
4 3 8 2 DESIGN ICC SYSTEM	1 DEC 82	28 FEB 83	28 FEB 83
4 3 8 3 PRODUCE "TO BE" ICC MODELS	1 DEC 82	28 FEB 83	28 FEB 83
4 3 8 4 PRODUCE ICC SYSTEM DESIGN SPEC	1 DEC 82	28 FEB 82	28 FEB 83
4 3 8 5 PRODUCE ICC IMPLEMENTATION PLAN	1 SEP 83	31 OCT 83	
4 3 8 6 ESTABLISH ICC TEST PLAN	1 JUL 83	30 AUG 83	
4 3 8 7 PRODUCE ICC DEVELOPMENT PLAN	1 MAR 83	30 JUN 83	
CDRL 3 DRAFT FINAL REPORT	1 NOV 83	30 NOV 83	

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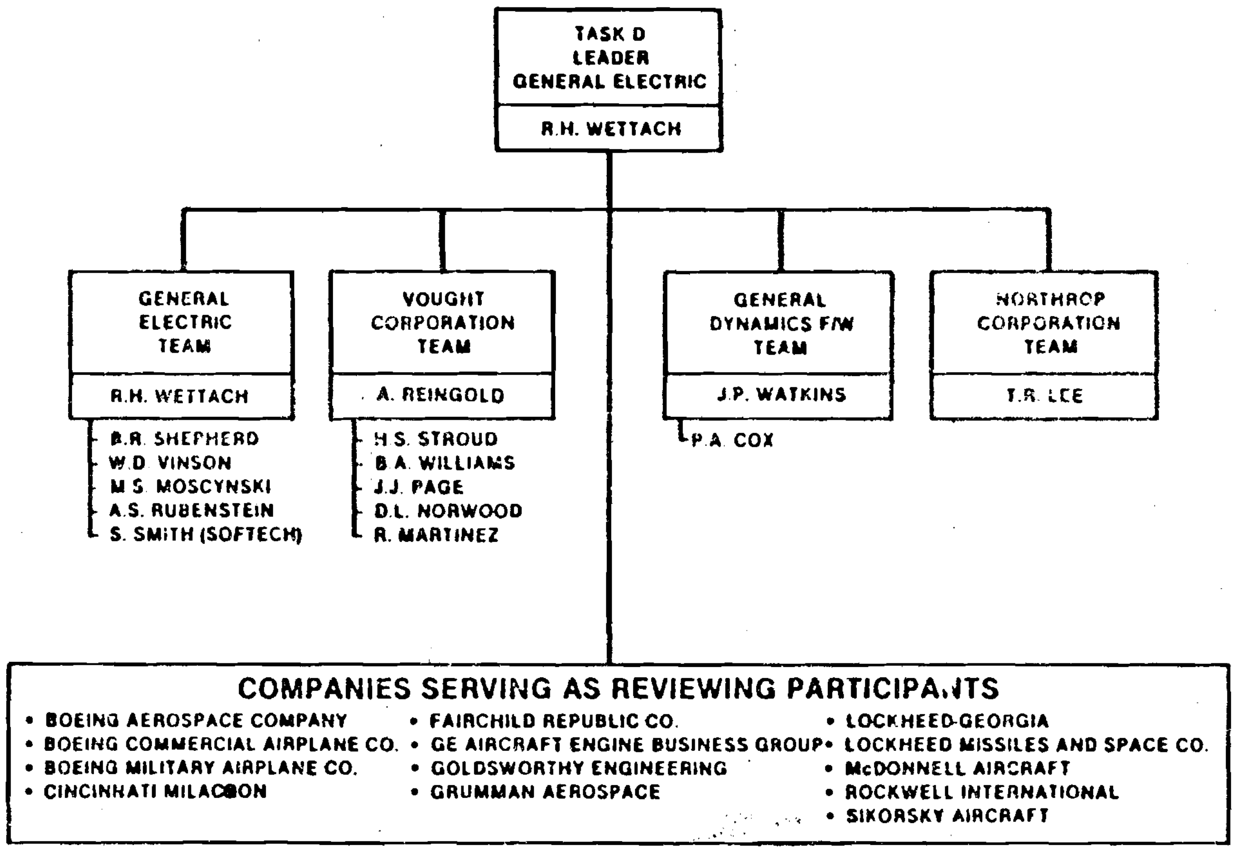
TASK D ORGANIZATION CHART



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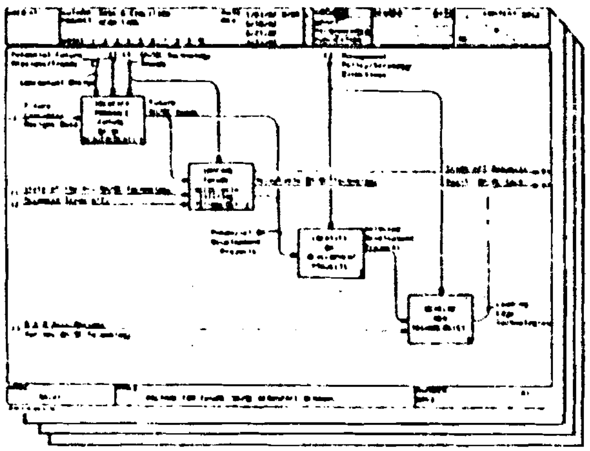
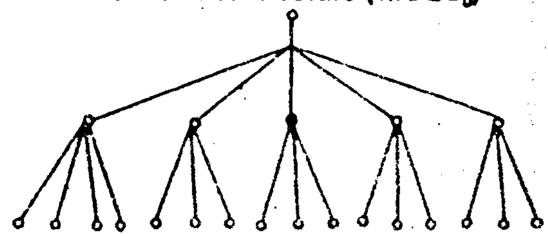
TASK D - Establishment of the "as is" architecture of QA/QC functions, ICAM quality assurance manual and a product assurance program standard

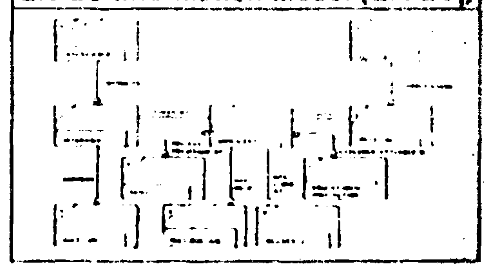
QA/QC Function Model (QA/QC$_0$)

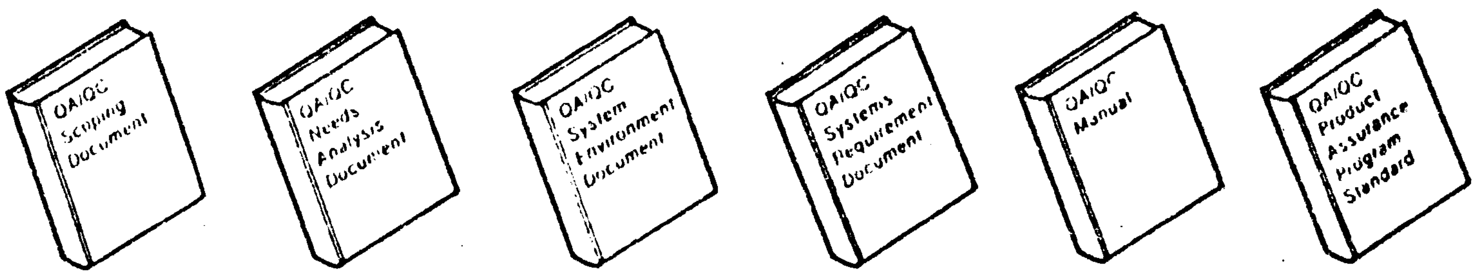


QA/QC Architecture (QA/QC$_0$)



QA/QC Information Model (QA/QC$_1$)





QA/Q Scoping Document	QA/QC Needs Analysis Document	QA/QC System Environment Document	QA/QC Systems Requirement Document	QA/QC Manual	QA/QC Product Assurance Program Standard

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TASK D MILESTONES

PROGRAM MILESTONES	START DATE	COMPLETION DATE TARGET	COMPLETION DATE ACTUAL
4.4 QA/QC TECHNICAL REQUIREMENTS	OCT 81	SEP 82	
4.4.1 PROJECT PLAN AND SCHEDULE	OCT 81	31 JAN 82	31 JAN 82
4.4.2 UNDERSTAND THE PROBLEM	JAN 82	31 MAR 83	
4.4.2.1 PERFORM NEEDS ANALYSIS	FEB 82	30 NOV 82	31 JAN 83
4.4.2.2 ESTABLISH "AS IS" ENVIRONMENT	JAN 82	31 DEC 82	31 DEC 82
4.4.2.3 ESTABLISH "AS-IS" COMPOSITE QA/QC MODELS	FEB 82	17 SEP 82	17 SEP 82
4.4.2.4 ESTABLISH "AS-IS" ARCHITECTURE INTERFACE	APR 82	31 DEC 82	31 DEC 82
4.4.2.5 ESTABLISH IMPROVEMENT CONCEPTS	JUL 82	31 MAR 83	
4.4.3 ESTABLISH QA/QC MANUAL	AUG 82	30 JUN 83	
4.4.4 ESTABLISH QA PROGRAM STANDARD	AUG 82	31 JUL 83	

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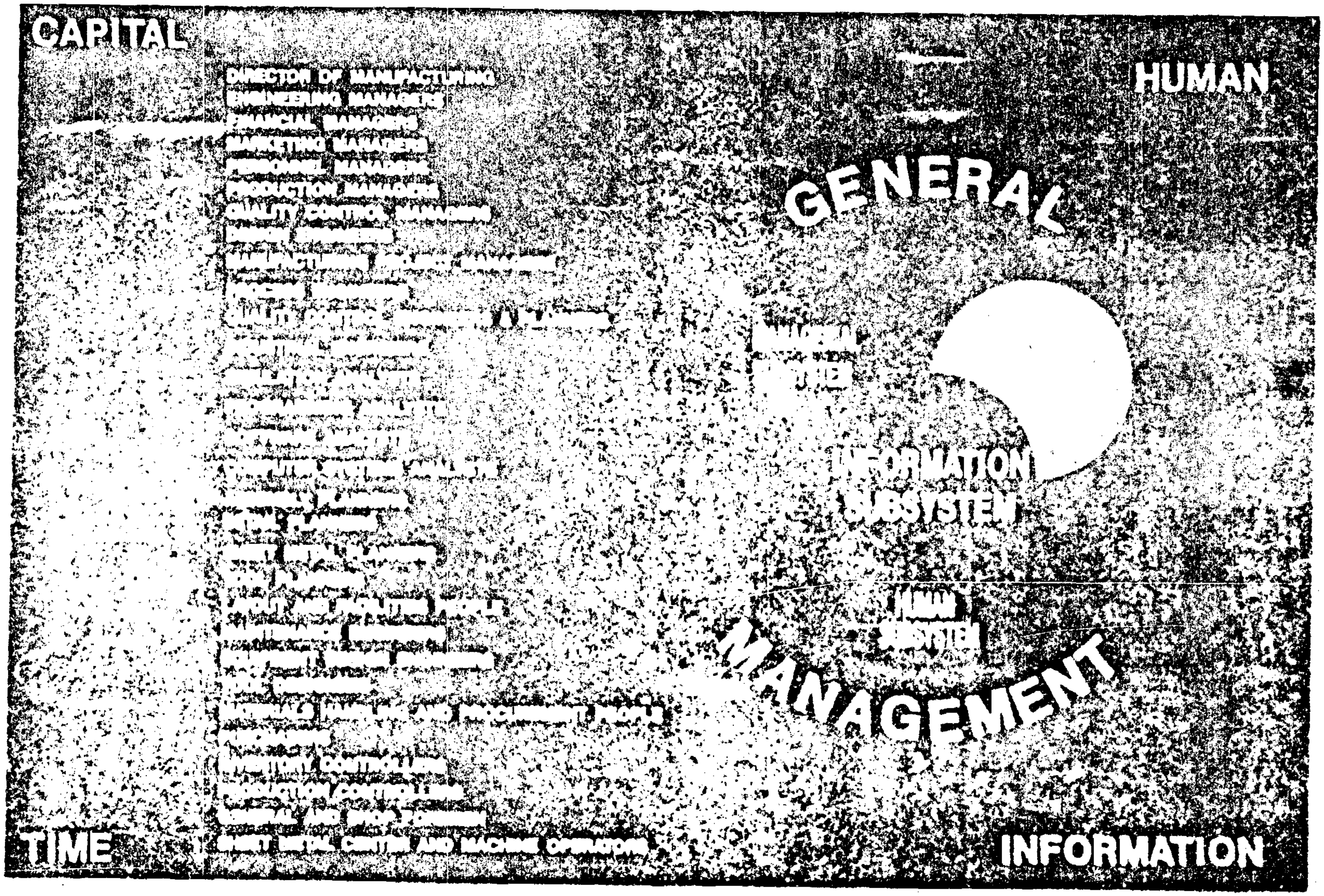
PROJECT 1105 – LIFE-CYCLE DOCUMENTS TO BE COMPLETED DURING CONTRACT

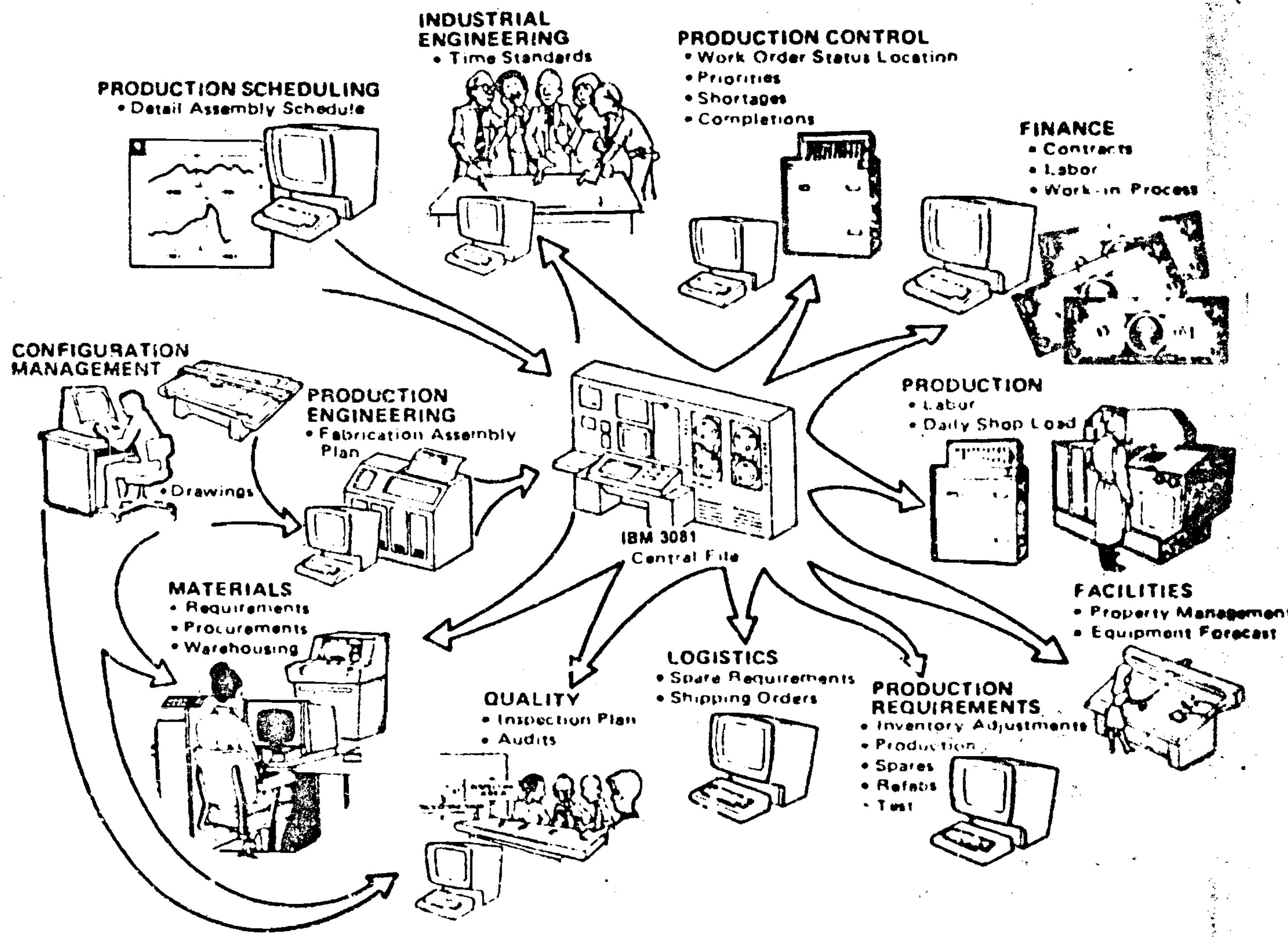
DELIVERABLES	ICAM LIFE CYCLE							
PHASE	UNDERSTAND PROBLEM		FORMULATE AND JUSTIFY SOLUTION		BUILD AND INTEGRATE SOLUTION		IMPLEMENT AND MAINTAIN SOLUTION	
STEP	NEEDS ANALYSIS	REQUIREMENTS DEFINITION	PRELIMINARY DESIGN	DETAIL DESIGN	CONSTRUCTION AND VERIFICATION TEST	INTEGRATION VALIDATION AND TEST	IMPLEMENT AND USE	MAINTAIN AND SUPPORT
SCOPING DOCUMENT (SD)	B C D							
NEEDS ANALYSIS DOCUMENT (NAD)	B C D							
SYSTEM ENVIRONMENT DOCUMENT (SED)	C D							
STATE OF THE ART DOCUMENT (SAD)		B C						
SYSTEMS REQUIREMENTS DOCUMENT (SRD)		B C D						
SYSTEM SPECIFICATION (SS)		B C						
SYSTEM DESIGN SPECIFICATION (SDS)			C					
SYSTEM TEST PLAN (STP)			C					
DEVELOPMENT SPECIFICATIONS (DS)			C					

B	C		IMPLEMENTATION PLAN DOCUMENT
		D	QA/QC MANUAL
		D	QA/QC PROGRAM STANDARD

P3-1627-17


CAPITAL
HUMAN
DIRECTOR OF MANUFACTURING
ENGINEERING MANAGERS
MARKETING MANAGERS
GENERAL
INFORMATION
SUBSYSTEM
MANAGEMENT
TIME
INFORMATION

29 June 1984



PRODUCTION SCHEDULING
• Detail Assembly Schedule
INDUSTRIAL ENGINEERING
• Time Standards
PRODUCTION CONTROL
• Work Order Status Location
• Priorities
• Shortages
• Completions
FINANCE
• Contracts
• Labor
• Work-in Process
CONFIGURATION MANAGEMENT
• Drawings
PRODUCTION ENGINEERING
• Fabrication Assembly Plan
PRODUCTION
• Labor
• Daily Shop Load
IBM 3081
Central File
MATERIALS
• Requirements
• Procurements
• Warehousing
FACILITIES
• Property Management
• Equipment Forecast
LOGISTICS
• Spare Requirements
• Shipping Orders
QUALITY
• Inspection Plan
• Audits
PRODUCTION REQUIREMENTS
• Inventory Adjustments
• Production
• Spares
• Refabs
• Test

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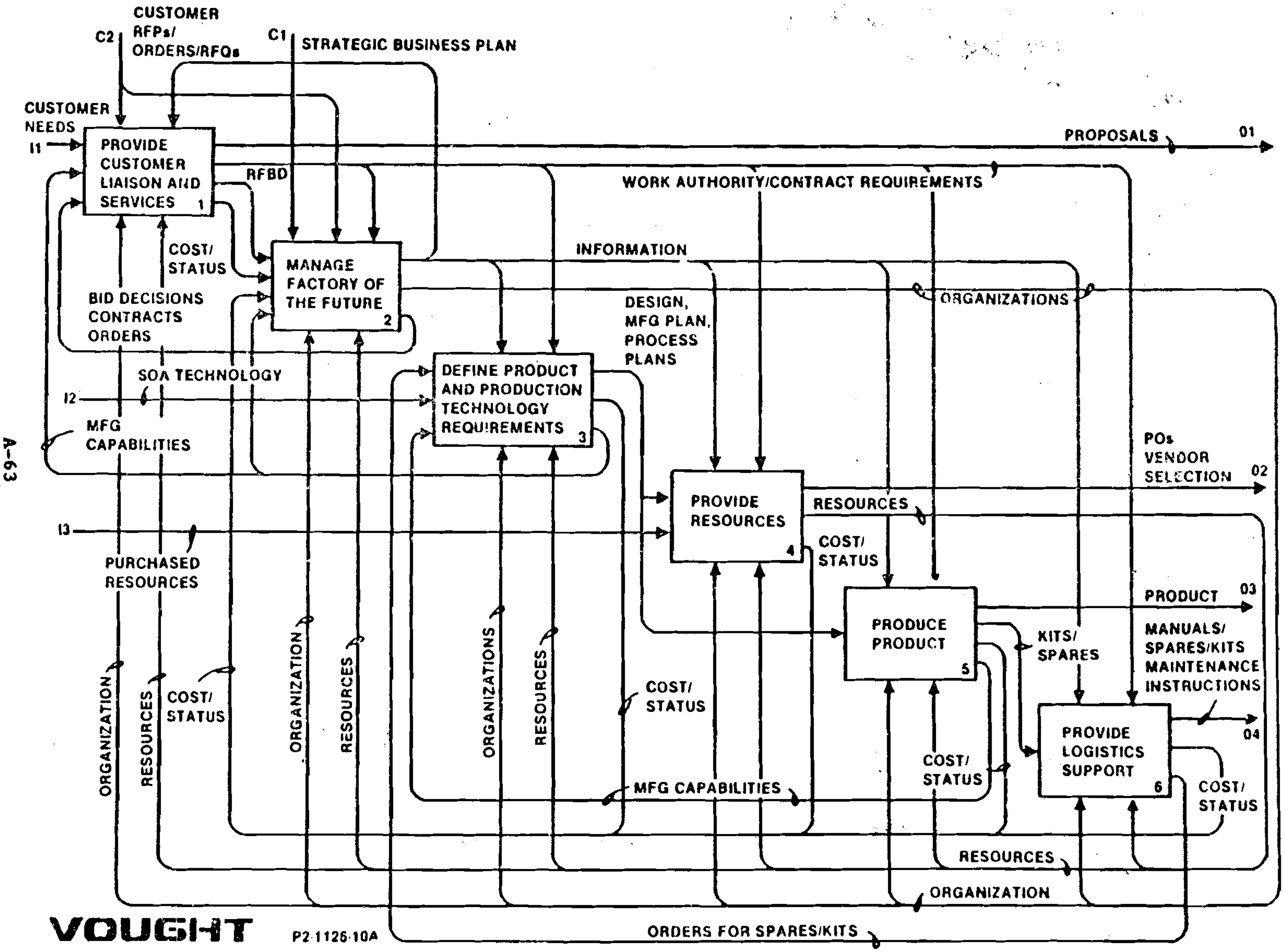
FACTORY OF THE FUTURE GENERIC FUNCTIONS



VOUGHT P2-1126-10A

A-63

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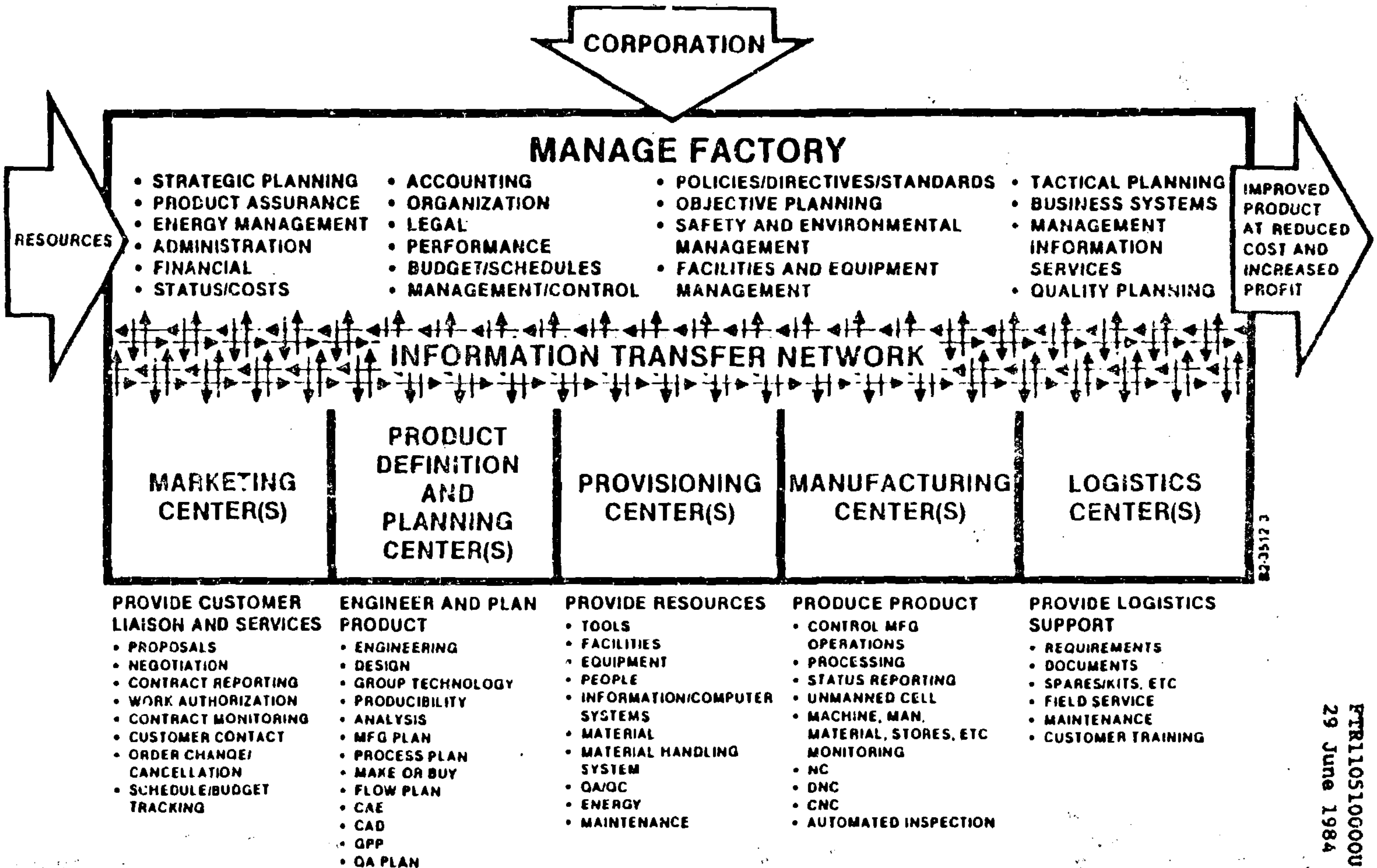
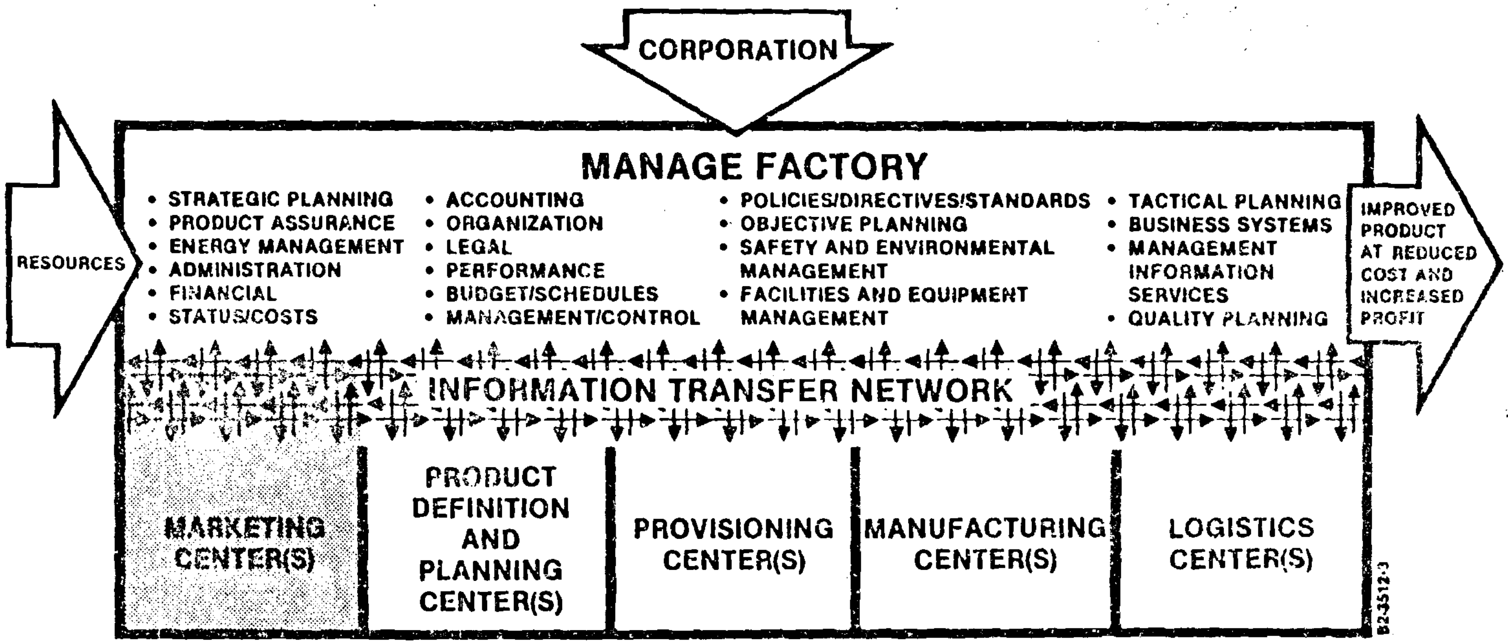
VOUGHT

FACTORY OF THE FUTURE FUNCTIONAL STRUCTURE



P3-1206-33A

FACTORY OF THE FUTURE FRAMEWORK



PROVIDE CUSTOMER LIAISON AND SERVICES
- PROPOSALS
- NEGOTIATION
- CONTRACT REPORTING
- WORK AUTHORIZATION
- CONTRACT MONITORING
- CUSTOMER CONTACT
- ORDER CHANGE/ CANCELLATION
- SCHEDULE/BUDGET TRACKING

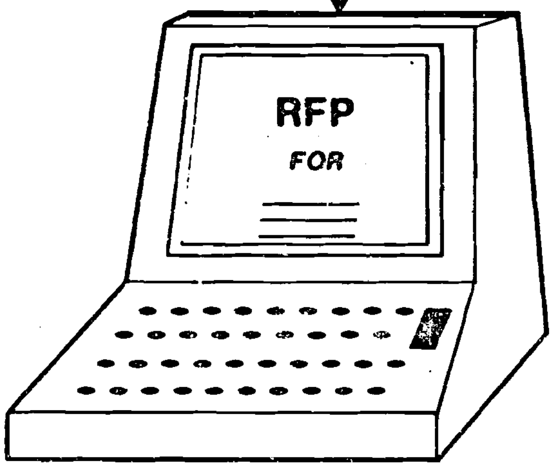
ENGINEER AND PLAN PRODUCT
- ENGINEERING
- DESIGN
- GROUP TECHNOLOGY
- PRODUCIBILITY
- ANALYSIS
- MFG PLAN
- PROCESS PLAN
- MAKE OR BUY
- FLOW PLAN
- CAE
- CAD
- GPP
- QA PLAN

PROVIDE RESOURCES
- TOOLS
- FACILITIES
- EQUIPMENT
- PEOPLE
- INFORMATION/COMPUTER SYSTEMS
- MATERIAL
- MATERIAL HANDLING SYSTEM
- QA/QC
- ENERGY
- MAINTENANCE

PRODUCE PRODUCT
- CONTROL MFG OPERATIONS
- PROCESSING
- STATUS REPORTING
- UNMANNED CELL
- MACHINE, MAN, MATERIAL, STORES, ETC MONITORING
- NC
- DNC
- CNC
- AUTOMATED INSPECTION

PROVIDE LOGISTICS SUPPORT
- REQUIREMENTS
- DOCUMENTS
- SPARES/KITS, ETC
- FIELD SERVICE
- MAINTENANCE
- CUSTOMER TRAINING

RFP → COMPANY DECISION PROCESS → BID/NO BID → PROPOSAL FOR → CUSTOMER



- ☐ Meets company business plan objectives
- ☐ Current plant capacity
  - Adequate
  - Inadquate
  - Facilities expansion, construction, etc.
- ☐ Have manufacturing technology and capability
  - Current processes adequate
  - New processes needed
- ☐ Human resources
  - Presently available
  - Obtainable
- ☐ Material availability and cost
- ☐ Subcontracts requirements

Determination of Company Capabilities

VOUGHT

P2-1126-2

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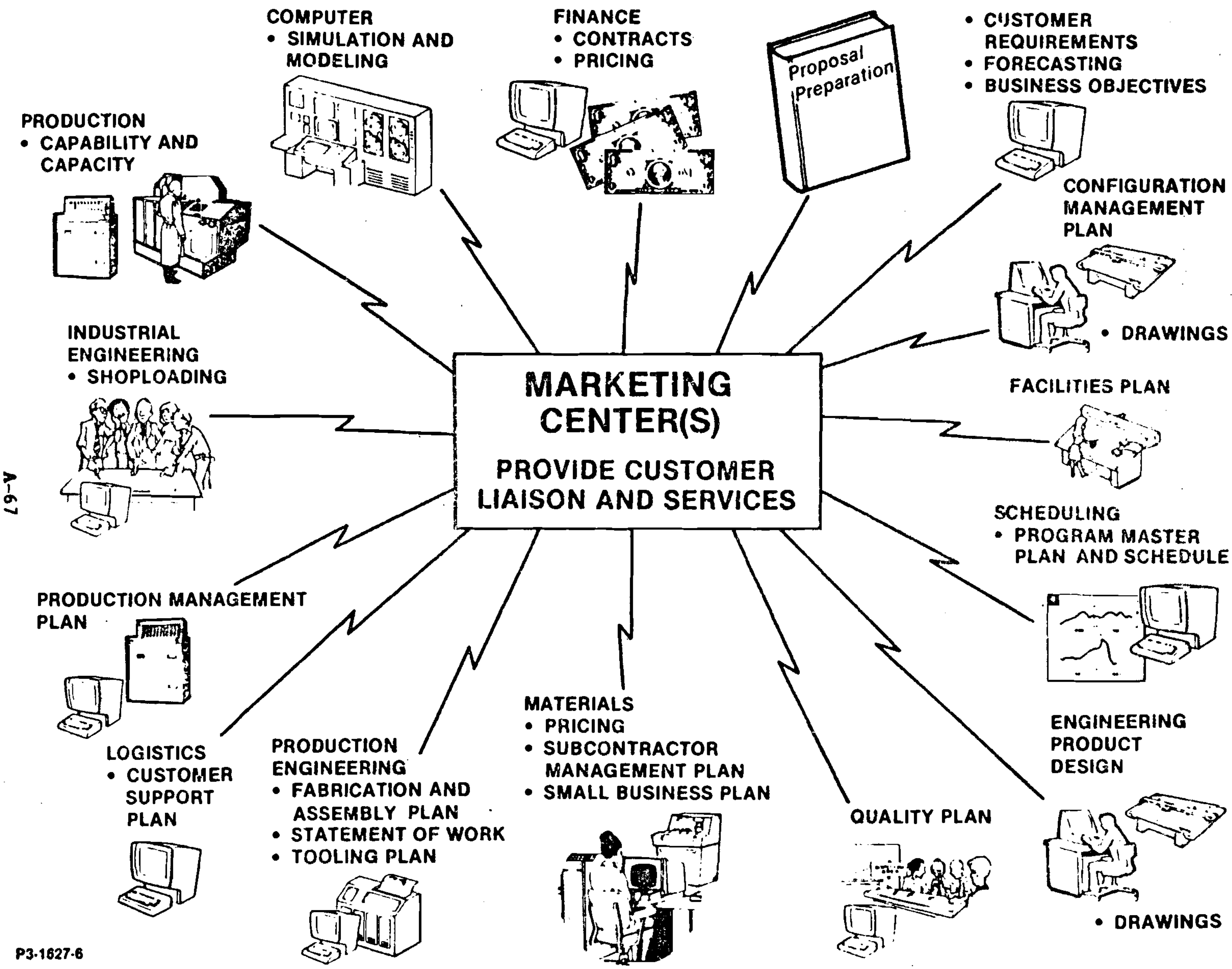
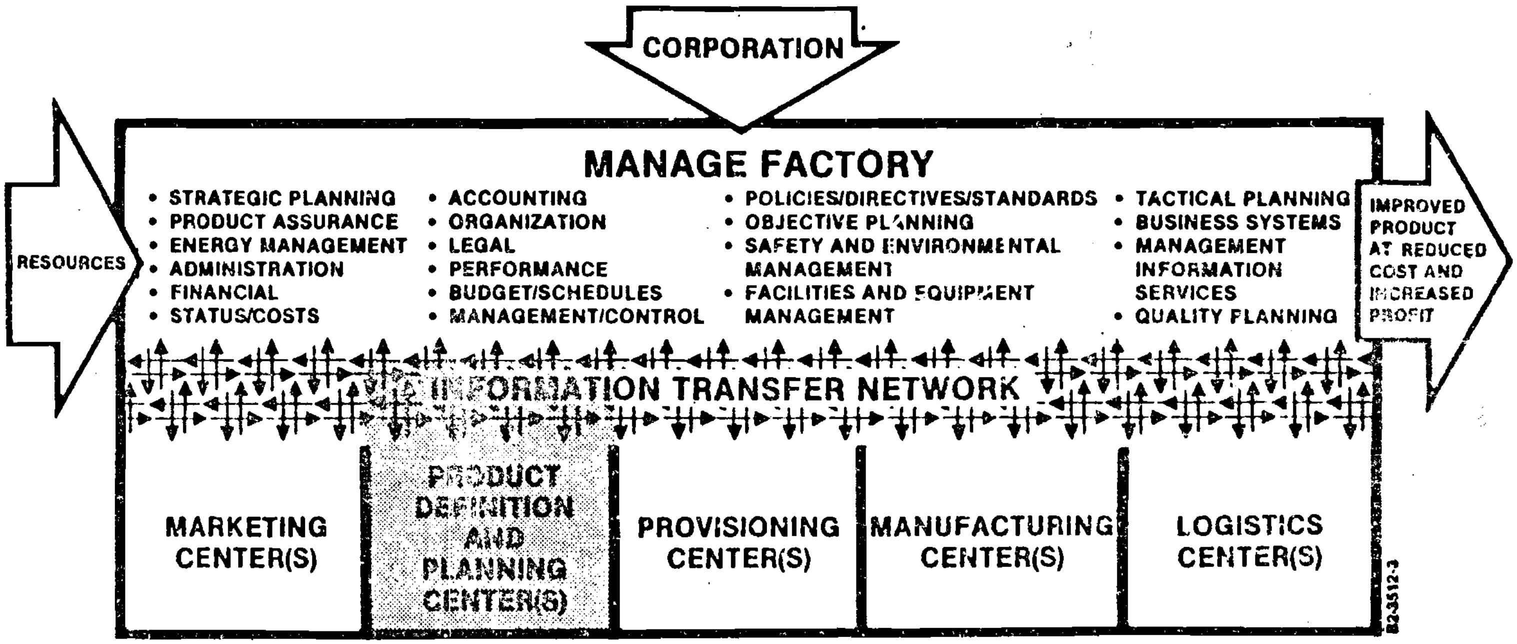
29 June 1984


COMPUTER
• SIMULATION AND MODELING
FINANCE
• CONTRACTS
• PRICING
Proposal Preparation
• CUSTOMER REQUIREMENTS
• FORECASTING
• BUSINESS OBJECTIVES
PRODUCTION
• CAPABILITY AND CAPACITY
CONFIGURATION MANAGEMENT PLAN
• DRAWINGS
INDUSTRIAL ENGINEERING
• SHOPLOADING
MARKETING CENTER(S)
PROVIDE CUSTOMER LIAISON AND SERVICES
FACILITIES PLAN
SCHEDULING
• PROGRAM MASTER PLAN AND SCHEDULE
PRODUCTION MANAGEMENT PLAN
ENGINEERING PRODUCT DESIGN
• DRAWINGS
LOGISTICS
• CUSTOMER SUPPORT PLAN
PRODUCTION ENGINEERING
• FABRICATION AND ASSEMBLY PLAN
• STATEMENT OF WORK
• TOOLING PLAN
MATERIALS
• PRICING
• SUBCONTRACTOR MANAGEMENT PLAN
• SMALL BUSINESS PLAN
QUALITY PLAN

P3-1627-6

FACTORY OF THE FUTURE FRAMEWORK



PROVIDE CUSTOMER LIAISON AND SERVICES
- PROPOSALS
- NEGOTIATION
- CONTRACT REPORTING
- WORK AUTHORIZATION
- CONTRACT MONITORING
- CUSTOMER CONTACT
- ORDER CHANGE/ CANCELLATION
- SCHEDULE/BUDGET TRACKING

ENGINEER AND PLAN PRODUCT
- ENGINEERING
- DESIGN
- GROUP TECHNOLOGY
- PRODUCIBILITY
- ANALYSIS
- MFG PLAN
- PROCESS PLAN
- MAKE OR BUY
- FLOW PLAN
- CAE
- CAD
- GPP
- QA PLAN

PROVIDE RESOURCES
- TOOLS
- FACILITIES
- EQUIPMENT
- PEOPLE
- INFORMATION/COMPUTER SYSTEMS
- MATERIAL
- MATERIAL HANDLING SYSTEM
- QA/QC
- ENERGY
- MAINTENANCE

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- CONTROL MFG OPERATIONS
- PROCESSING
- STATUS REPORTING
- UNMANNED CELL
- MACHINE, MAN, MATERIAL, STORES, ETC MONITORING
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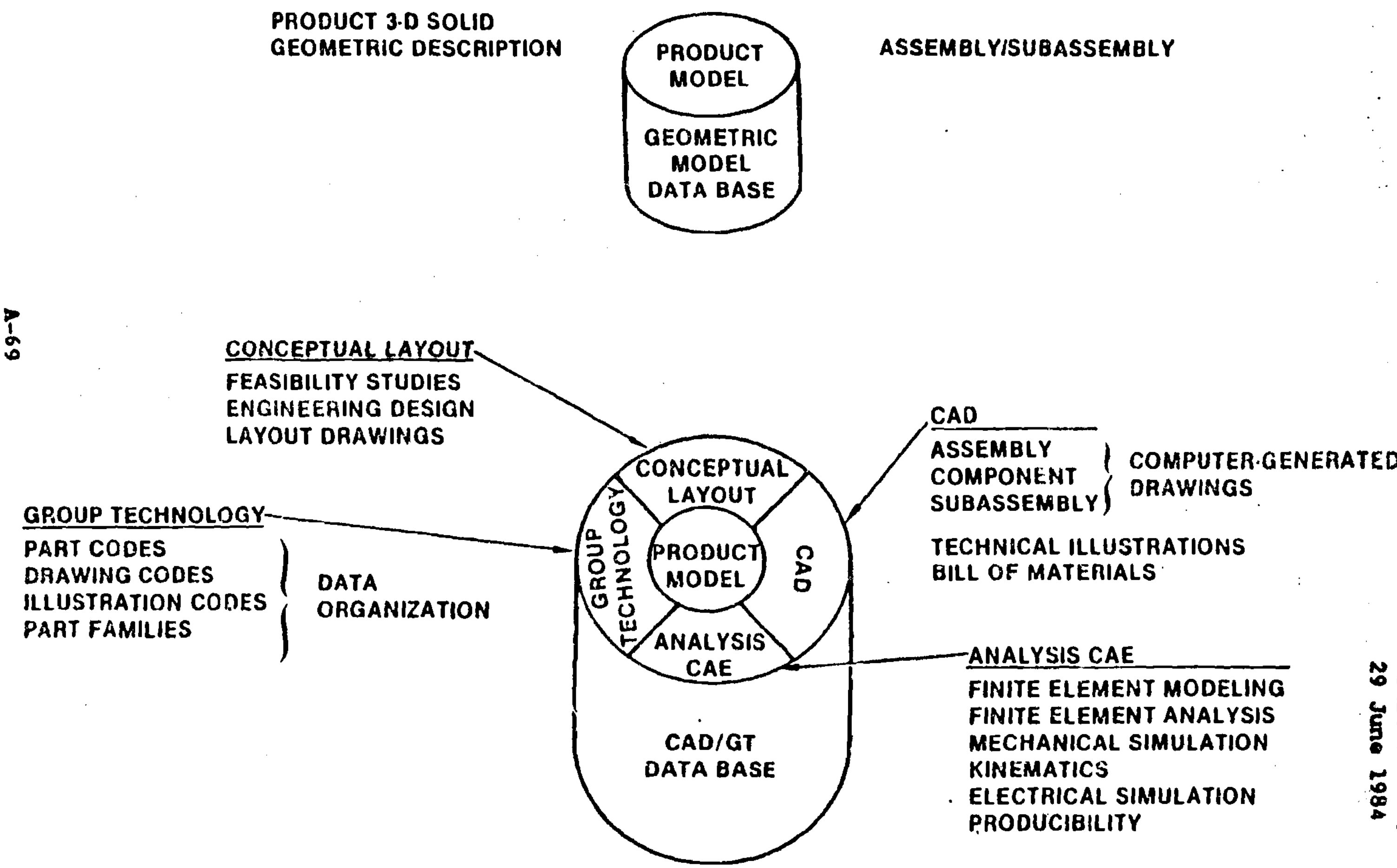
- AUTOMATED INSPECTION

PROVIDE LOGISTICS SUPPORT
- REQUIREMENTS
- DOCUMENTS
- SPARES/KITS, ETC
- FIELD SERVICE
- MAINTENANCE
- CUSTOMER TRAINING

PRODUCT DEFINITION AND PLANNING



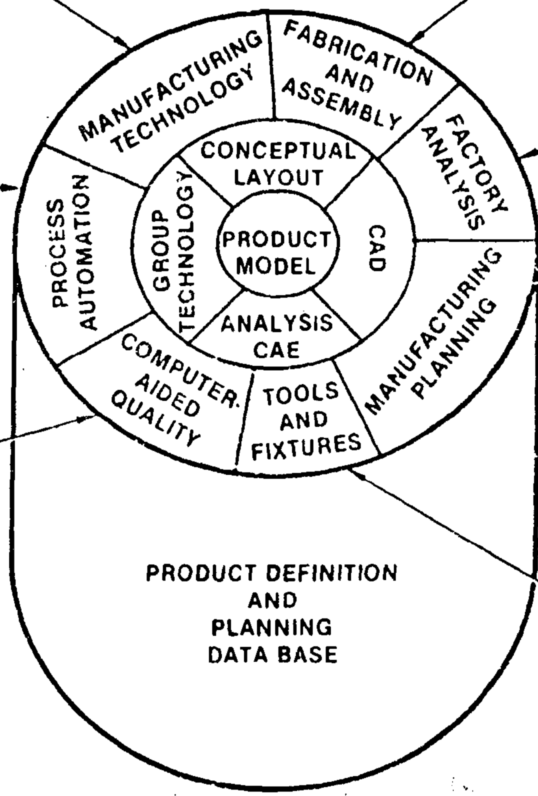
P2-1126-1

PRODUCT DEFINITION AND PLANNING

MANUFACTURING TECHNOLOGY
- MANUFACTURING INFO SYSTEMS
- PROCESS TECHNOLOGY
- MRP
- SCHEDULING
- DECISION SUPPORT SYSTEMS
- GROUP TECHNOLOGY

PROCESS AUTOMATION
- ROBOTICS PROGRAMMING/SIMULATION FOR: MACHINING, SHEET METAL, COMPOSITES, ELECTRICAL, ASSEMBLY
- PROGRAMMABLE LOGIC CONTROLLERS
- GROUP TECHNOLOGY

COMPUTER-AIDED QUALITY
- COORDINATE MEASURING MACHINES
- ELECTRICAL TESTS
- VERIFICATION
- NONDESTRUCTIVE TESTING
- PRODUCT ASSURANCE REPORTS
- GROUP TECHNOLOGY



FABRICATION AND ASSEMBLY
- SHEET METAL
- MACHINING
- COMPOSITES
- ELECTRICAL
- ASSEMBLY
- NC
- PRODUCTION CONTROL
- GROUP TECHNOLOGY

FACTORY ANALYSIS
- FACTORY MODELING/SIMULATION
- GROUP TECHNOLOGY ANALYSIS
- PROCESS FLOW
- PRODUCIBILITY

MANUFACTURING PLANNING
- COMPUTER-AIDED PROCESS PLANNING: SHEET METAL, MACHINING, COMPOSITES, ELECTRICAL, ASSEMBLY
- PROCESS PLAN PICTORIALS
- TIME STANDARDS
- COST ESTIMATING
- PROJECT CONTROL SYSTEM
- GROUP TECHNOLOGY
- MAKE/BUY

TOOLS AND FIXTURES
- DESIGN OF: TOOLS, FIXTURES, MOLDS, PRODUCTION EQUIPMENT
- GROUP TECHNOLOGY

P2-1126-2

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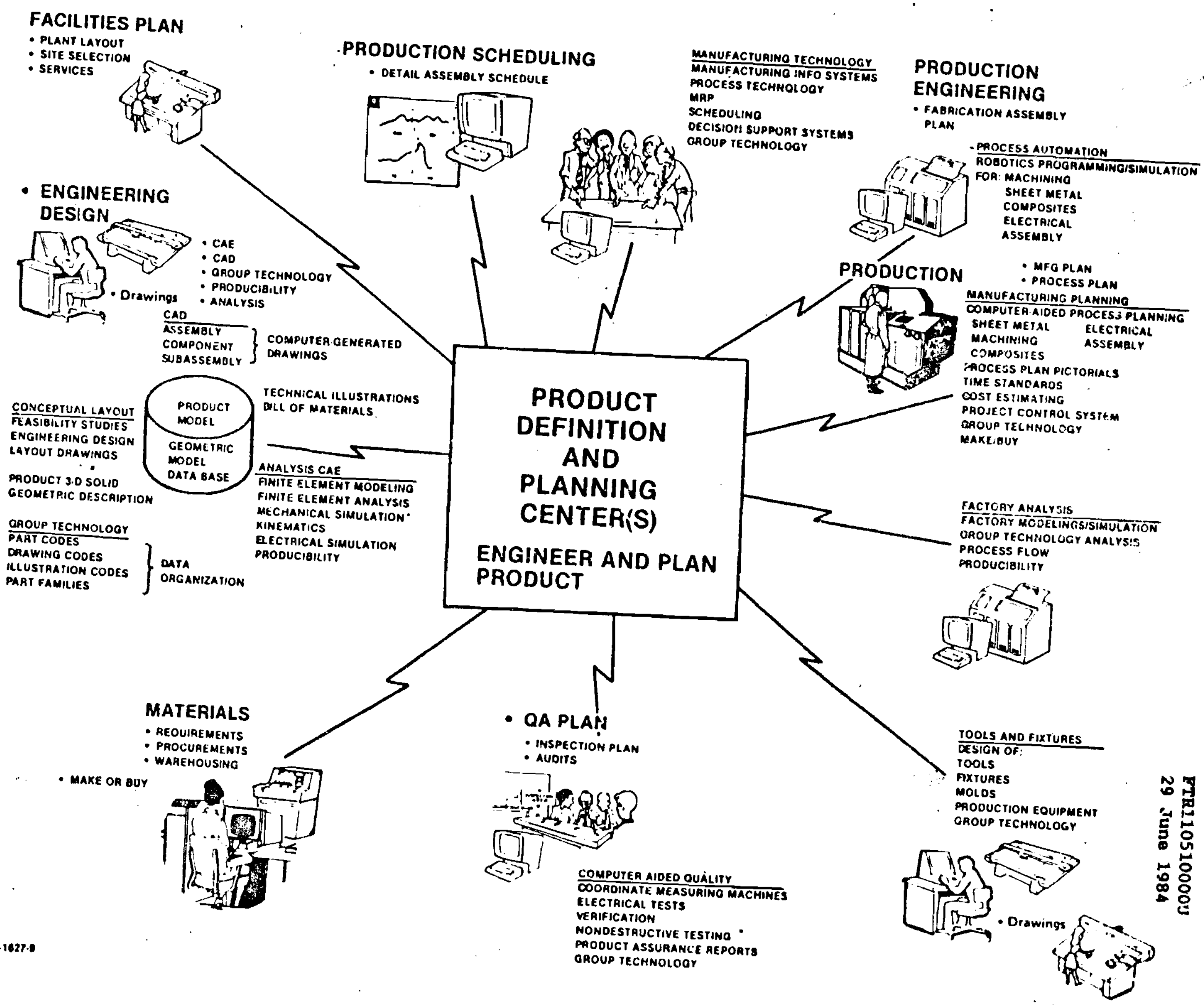

P3-1627-9

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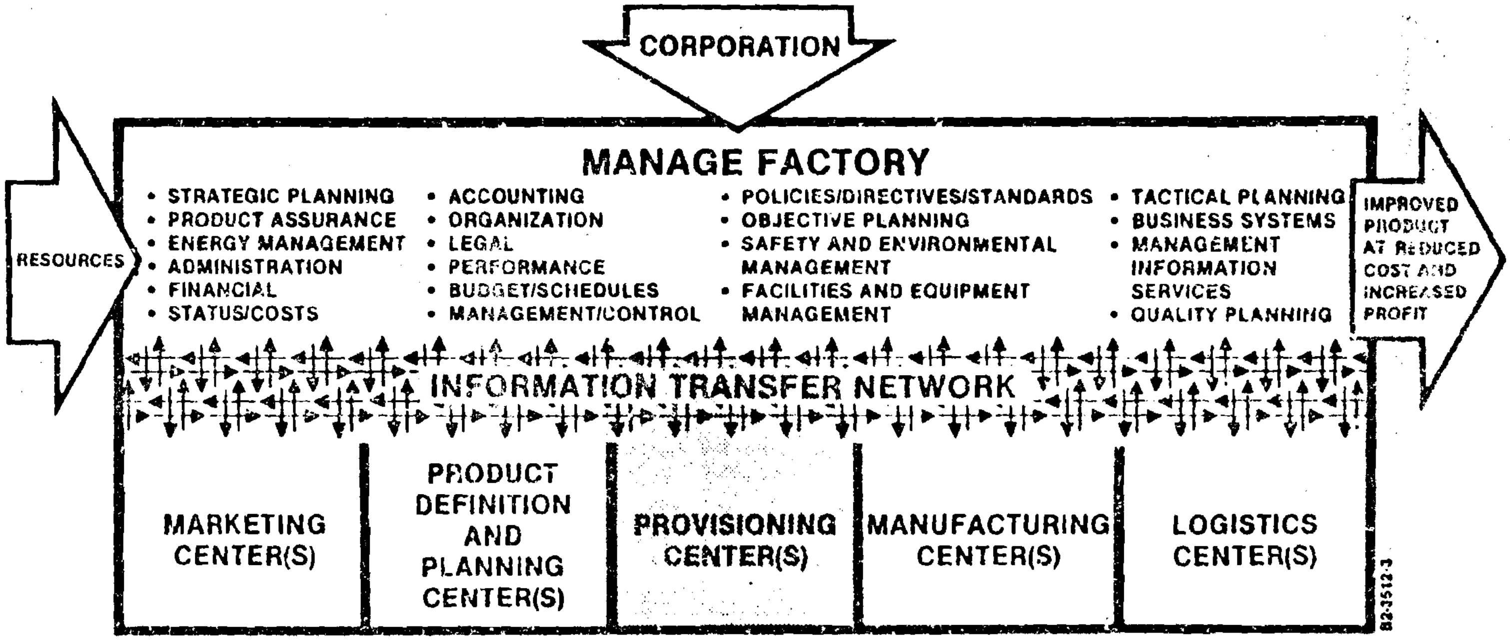
29 June 1984

FACTORY OF THE FUTURE FRAMEWORK



PROVIDE CUSTOMER LIAISON AND SERVICES
- PROPOSALS
- NEGOTIATION
- CONTRACT REPORTING
- WORK AUTHORIZATION
- CONTRACT MONITORING
- CUSTOMER CONTACT
- ORDER CHANGE/ CANCELLATION
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- PROCESSING
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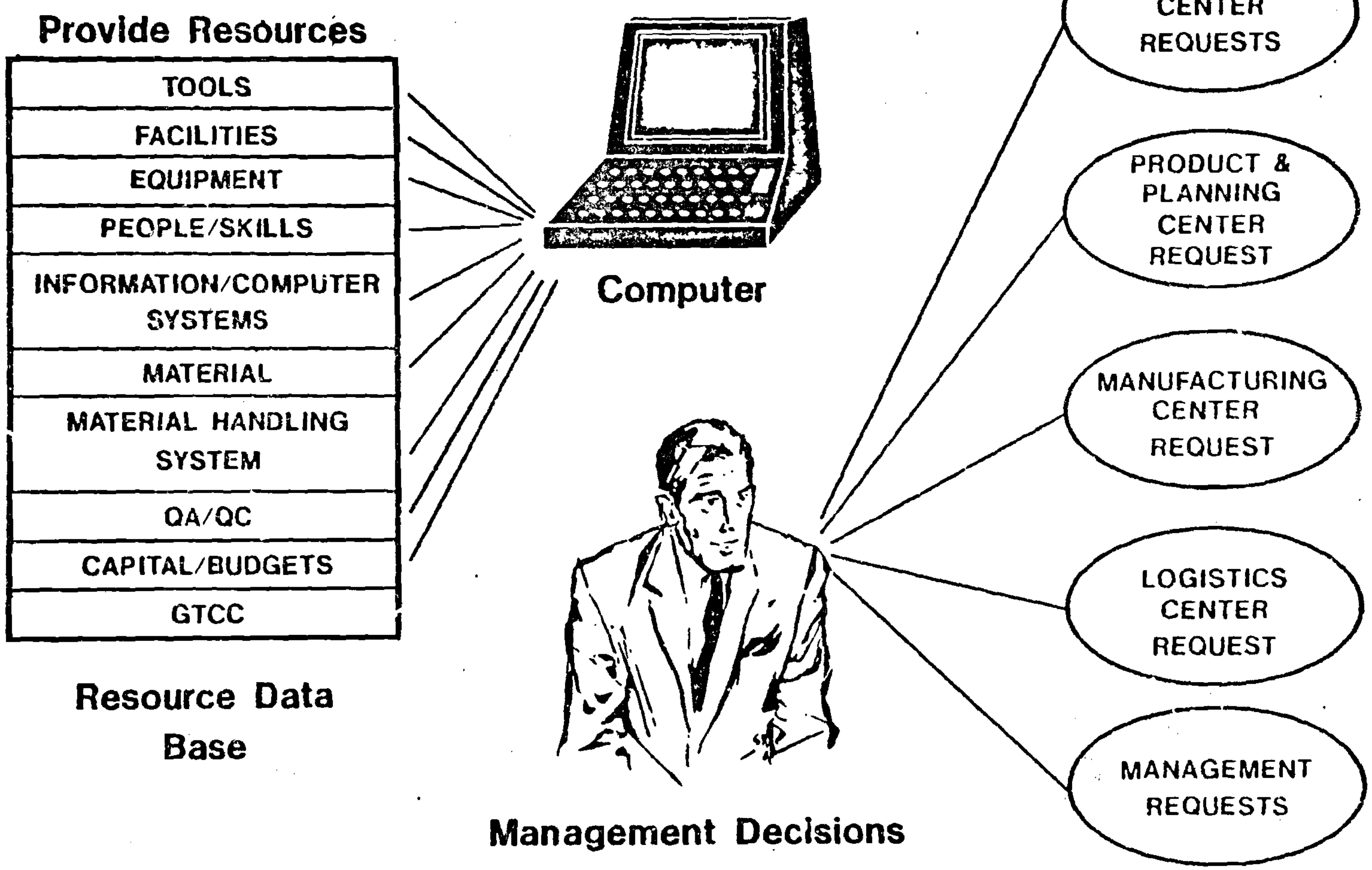
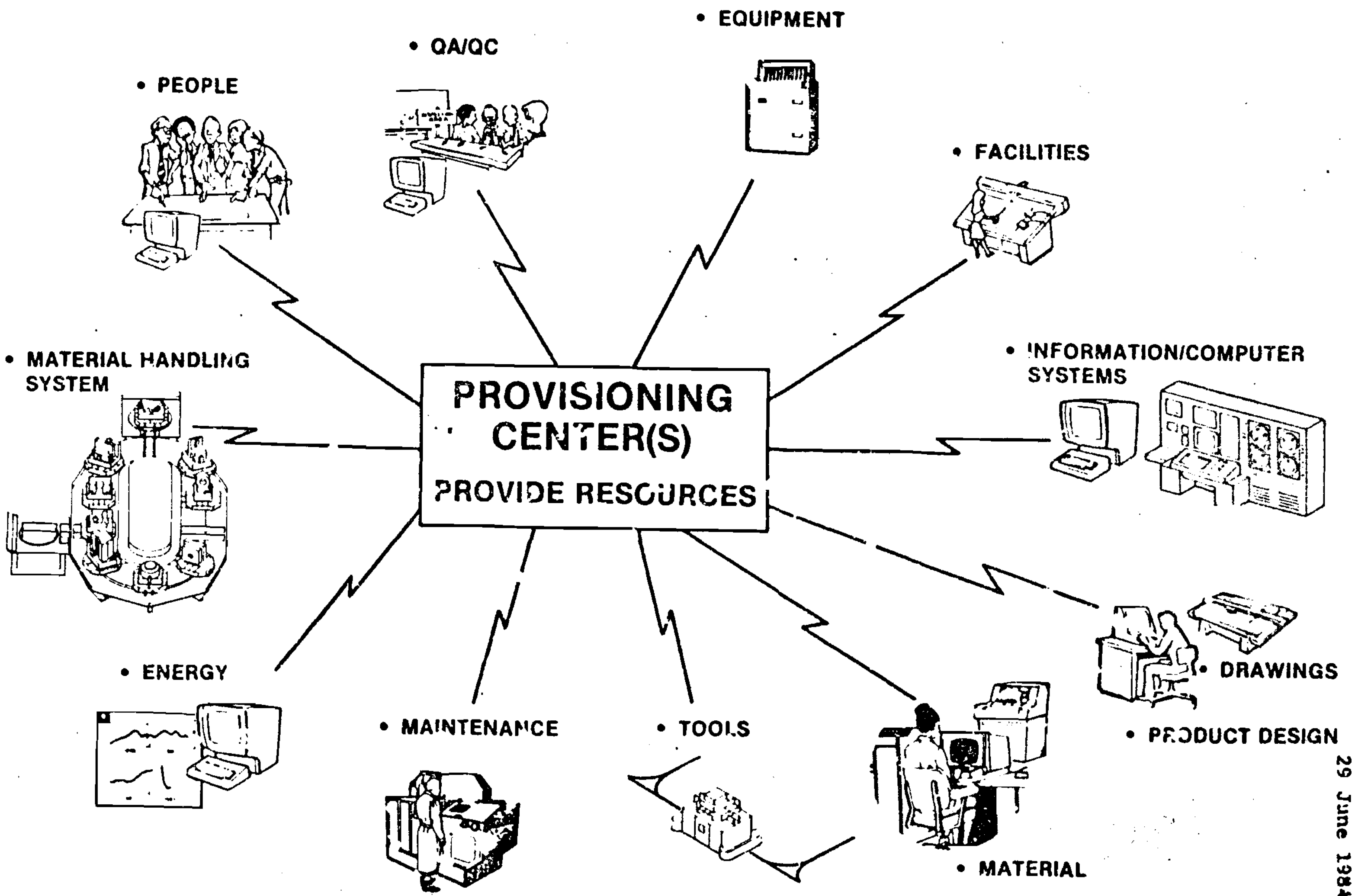
- DNC
- CNC
- AUTOMATED INSPECTION

PROVIDE LOGISTICS SUPPORT
- REQUIREMENTS
- DOCUMENTS
- SPARES/KITS, ETC
- FIELD SERVICE
- MAINTENANCE
- CUSTOMER TRAINING

Provisioning



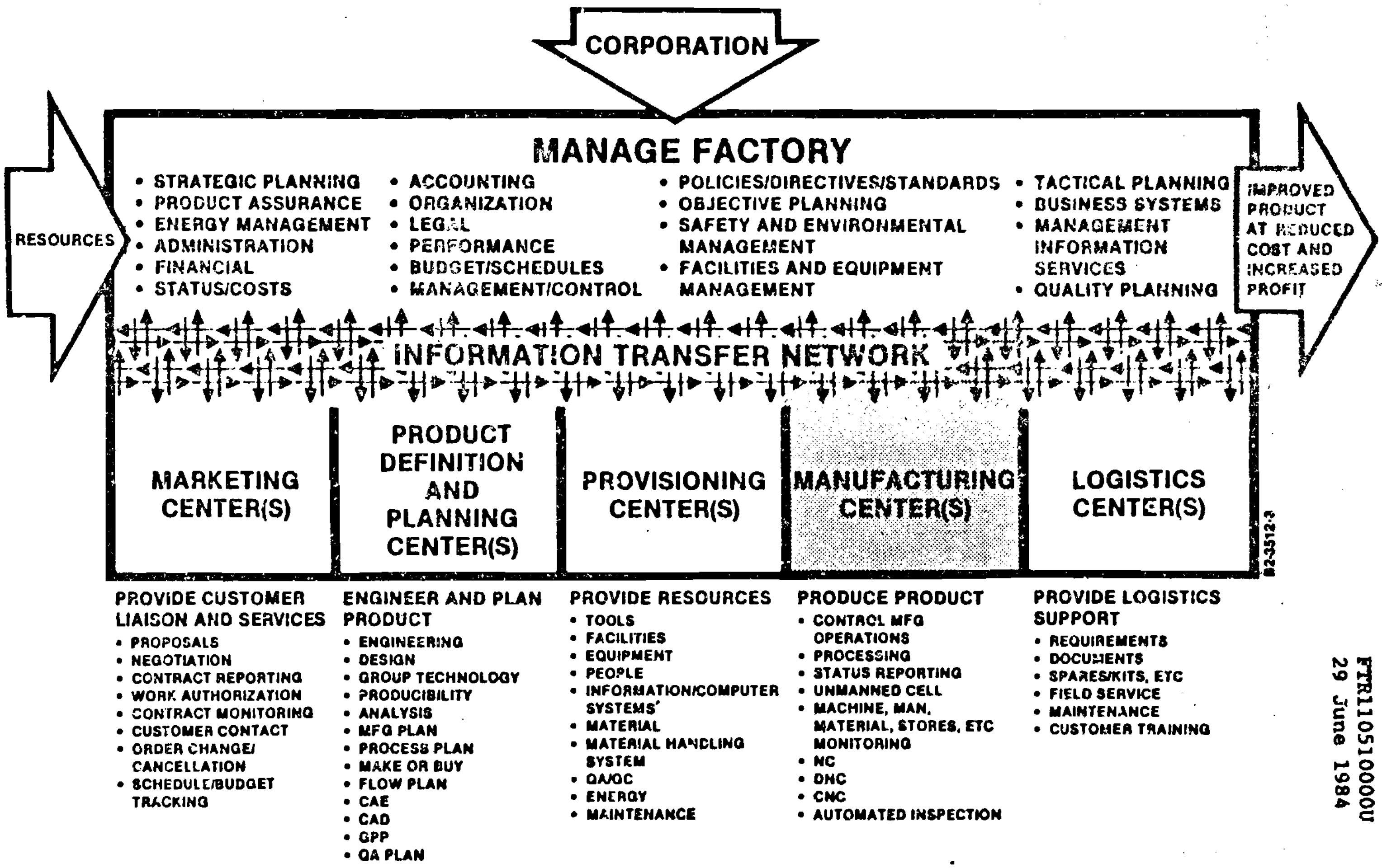
P2-1126-19



P3-1627-10

FTR110510000U
29 June 1984

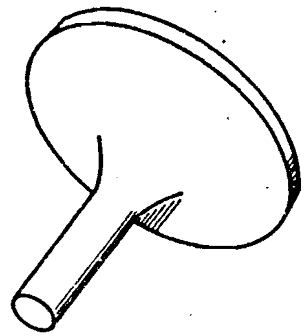
FACTORY OF THE FUTURE FRAMEWORK



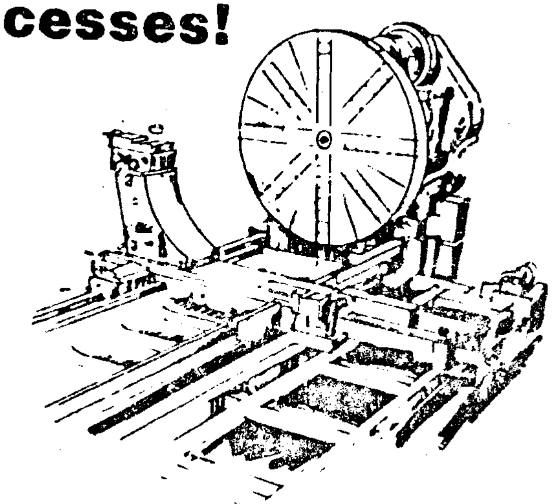
VOUGHT

Manufacturing Decisions Effect the Production Processes!

Management



Components

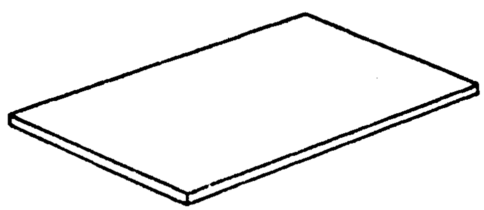


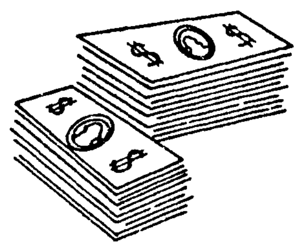
Resources

±.005

Quality

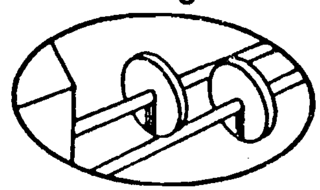
Material



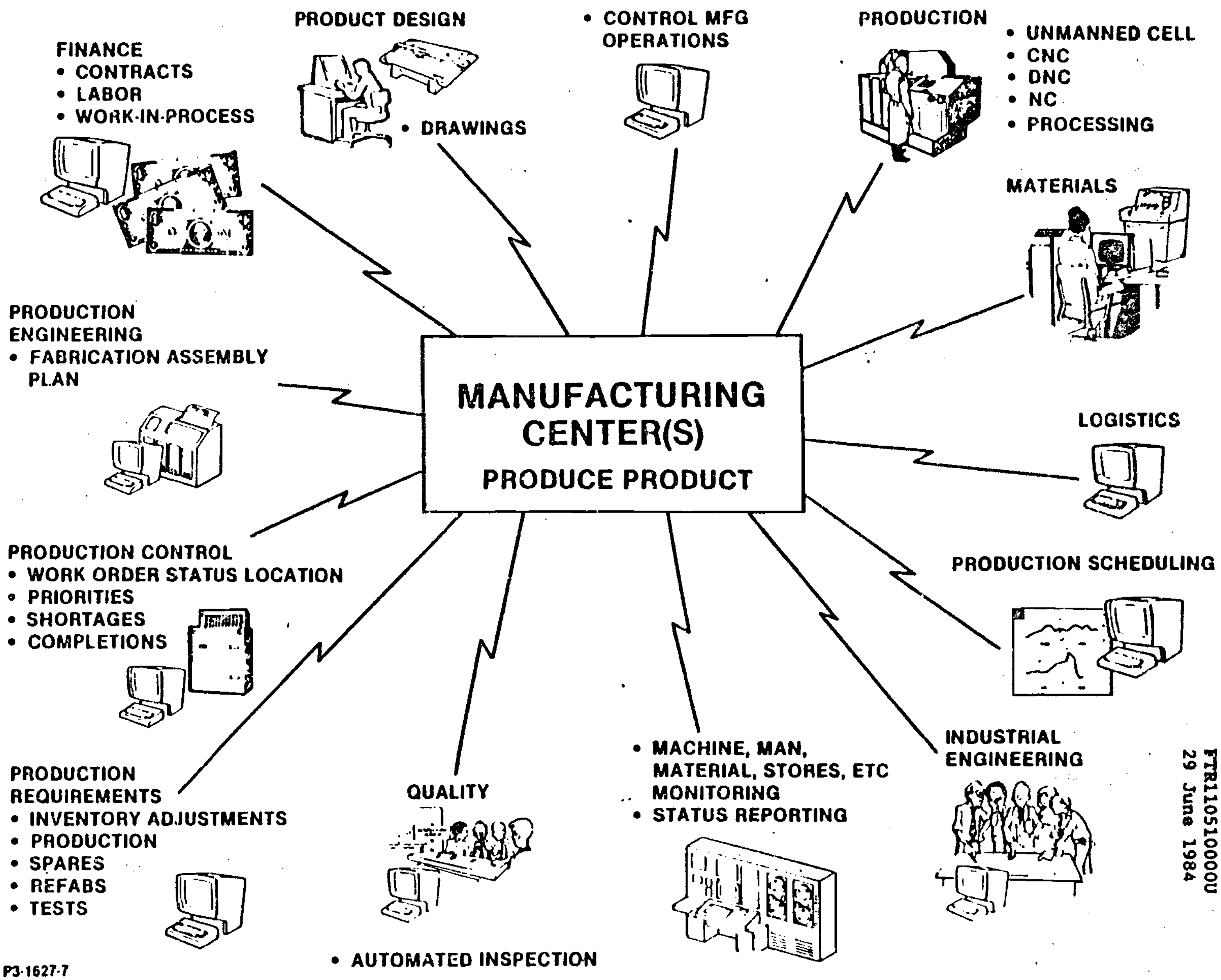


Finance

Design

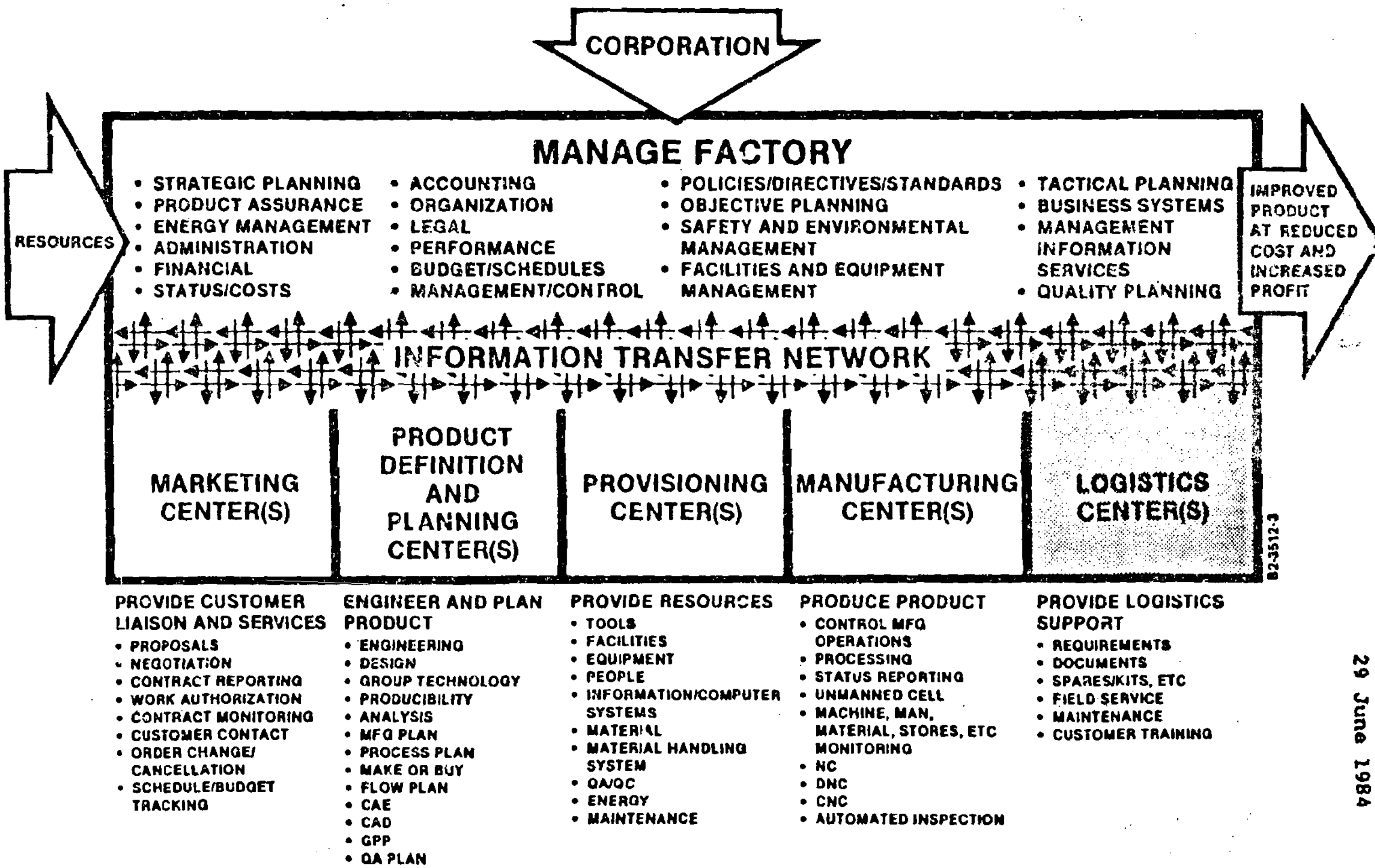


P0-2351-3


MANUFACTURING CENTER(S)
PRODUCE PRODUCT
FINANCE
• CONTRACTS
• LABOR
• WORK-IN-PROCESS
PRODUCT DESIGN
• DRAWINGS
• CONTROL MFG OPERATIONS
PRODUCTION
• UNMANNED CELL
• CNC
• DNC
• NC
• PROCESSING
MATERIALS
LOGISTICS
PRODUCTION SCHEDULING
INDUSTRIAL ENGINEERING
• MACHINE, MAN, MATERIAL, STORES, ETC MONITORING
• STATUS REPORTING
QUALITY
• AUTOMATED INSPECTION
PRODUCTION REQUIREMENTS
• INVENTORY ADJUSTMENTS
• PRODUCTION
• SPARES
• REFABS
• TESTS
PRODUCTION CONTROL
• WORK ORDER STATUS LOCATION
• PRIORITIES
• SHORTAGES
• COMPLETIONS
PRODUCTION ENGINEERING
• FABRICATION ASSEMBLY PLAN

P3-1627-7

FACTORY OF THE FUTURE FRAMEWORK



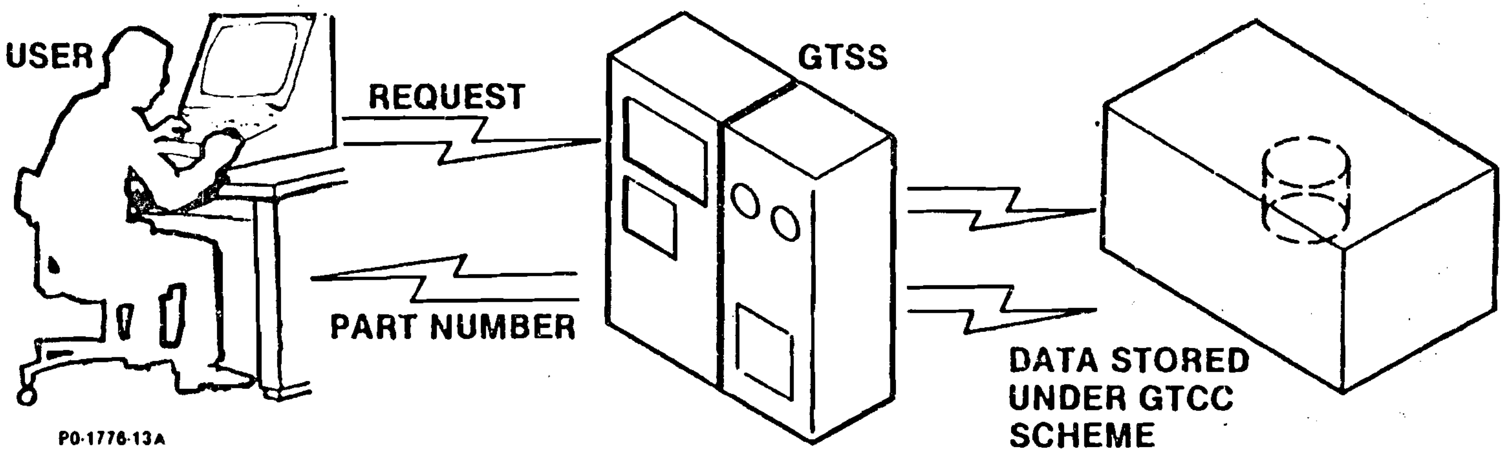
VOUGHT

Logistics

PROBLEM: SOME PARTS MADE FROM 7075-T6 ALUMINUM WITH STIFFENING BEADS (CVD NO. 3078) ARE DEVELOPING STRESS CRACKS

SOLUTION:

1. SEARCH STORED DATA FOR ALL PARTS WHICH ARE:
   - MADE OF 7075-T6 ALUMINUM
   - HAVE BEAD CVD NO. 3078
2. NOTE: PART NUMBERS SUBJECT TO POSSIBLE CRACK DEFECTS



A-79

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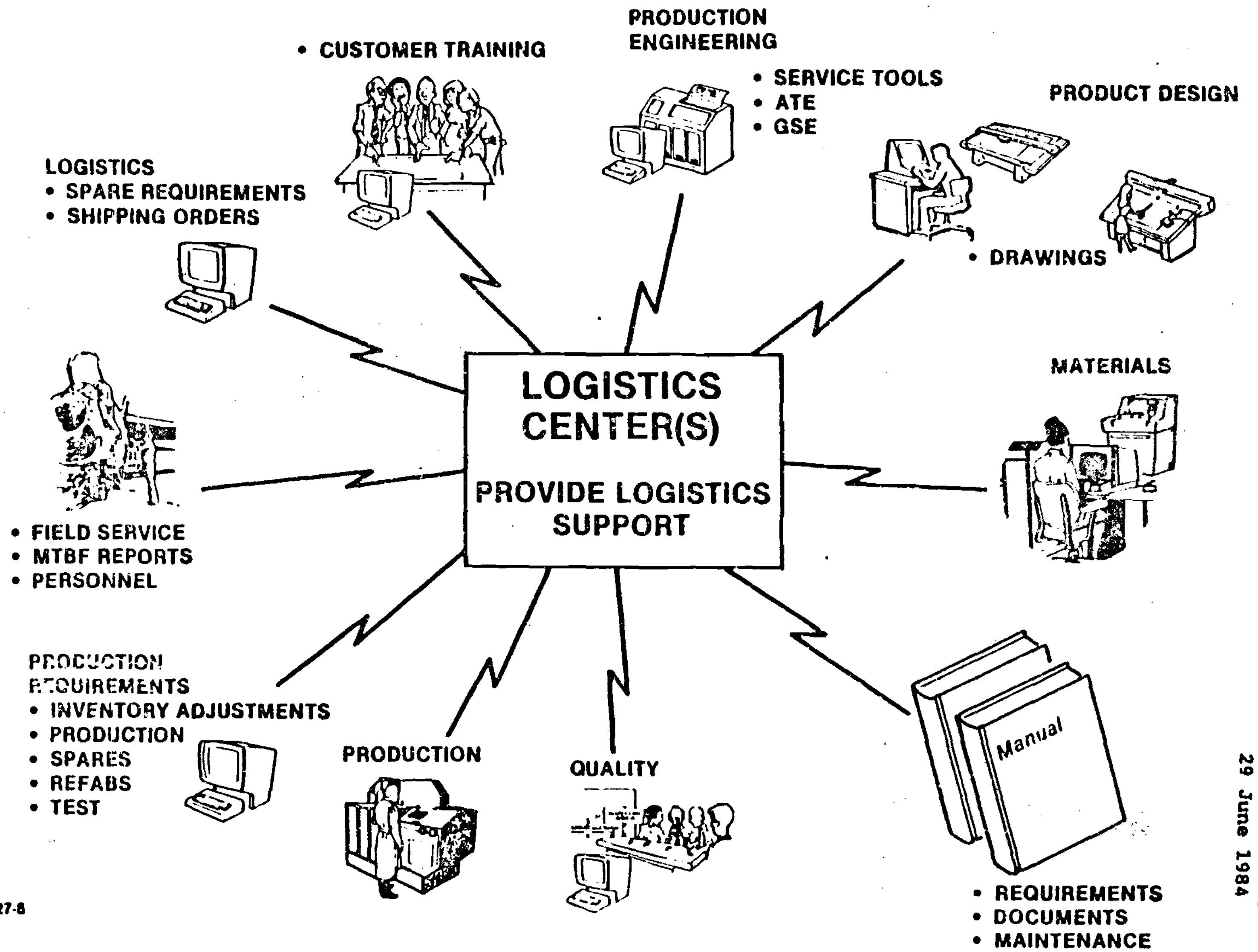
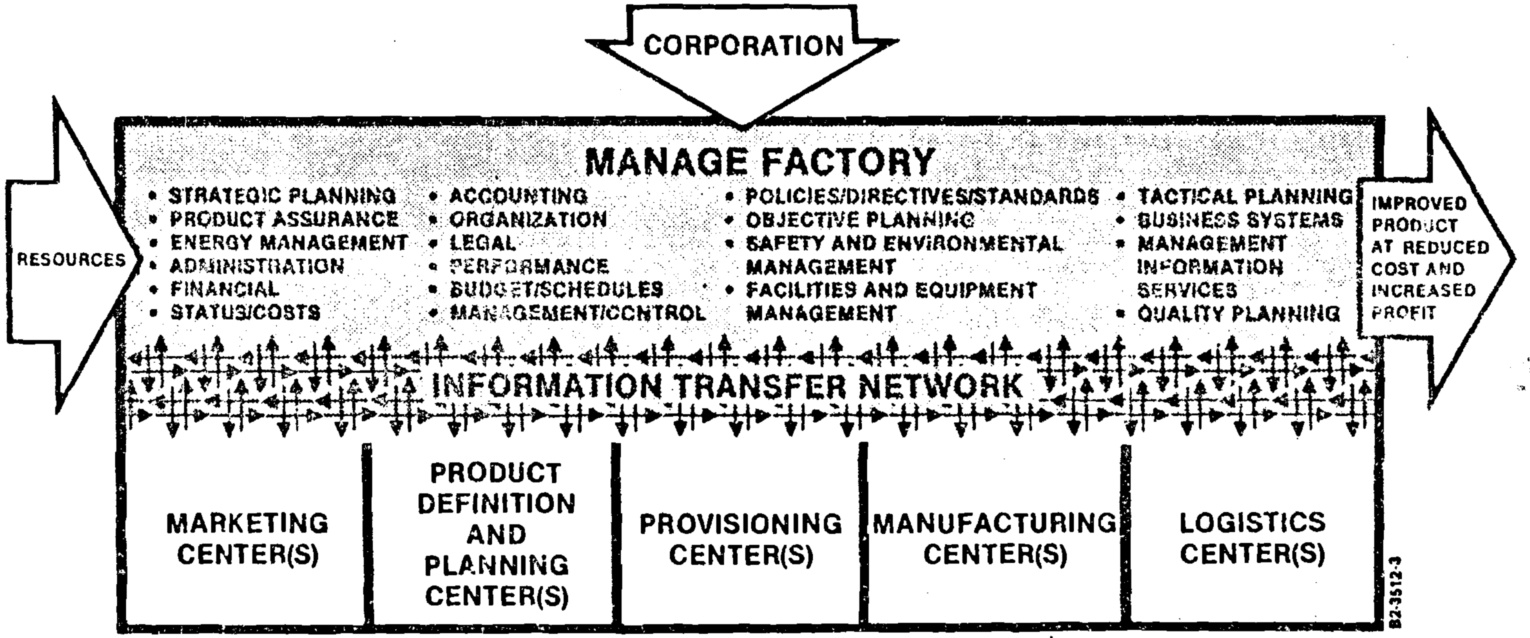

LOGISTICS CENTER(S)
PROVIDE LOGISTICS SUPPORT
• CUSTOMER TRAINING
PRODUCTION ENGINEERING
• SERVICE TOOLS
• ATE
• GSE
PRODUCT DESIGN
• DRAWINGS
LOGISTICS
• SPARE REQUIREMENTS
• SHIPPING ORDERS
MATERIALS
• FIELD SERVICE
• MTBF REPORTS
• PERSONNEL
PRODUCTION REQUIREMENTS
• INVENTORY ADJUSTMENTS
• PRODUCTION
• SPARES
• REFABS
• TEST
PRODUCTION
QUALITY
Manual
• REQUIREMENTS
• DOCUMENTS
• MAINTENANCE

P3-1627-8

FACTORY OF THE FUTURE FRAMEWORK



PROVIDE CUSTOMER LIAISON AND SERVICES
- PROPOSALS
- NEGOTIATION
- CONTRACT REPORTING
- WORK AUTHORIZATION
- CONTRACT MONITORING
- CUSTOMER CONTACT
- ORDER CHANGE/ CANCELLATION
- SCHEDULE/BUDGET TRACKING

ENGINEER AND PLAN PRODUCT
- ENGINEERING
- DESIGN
- GROUP TECHNOLOGY
- PRODUCIBILITY
- ANALYSIS
- MFG PLAN
- PROCESS PLAN
- MAKE OR BUY
- FLOW PLAN
- CAE
- CAD
- GPP
- QA PLAN

PROVIDE RESOURCES
- TOOLS
- FACILITIES
- EQUIPMENT
- PEOPLE
- INFORMATION/COMPUTER SYSTEMS
- MATERIAL
- MATERIAL HANDLING SYSTEM
- QA/QC
- ENERGY
- MAINTENANCE

PRODUCE PRODUCT
- CONTROL MFG OPERATIONS
- PROCESSING
- STATUS REPORTING
- UNMANNED CELL
- MACHINE, MAN, MATERIAL, STORES, ETC MONITORING
- NC
- DNC
- CNC
- AUTOMATED INSPECTION

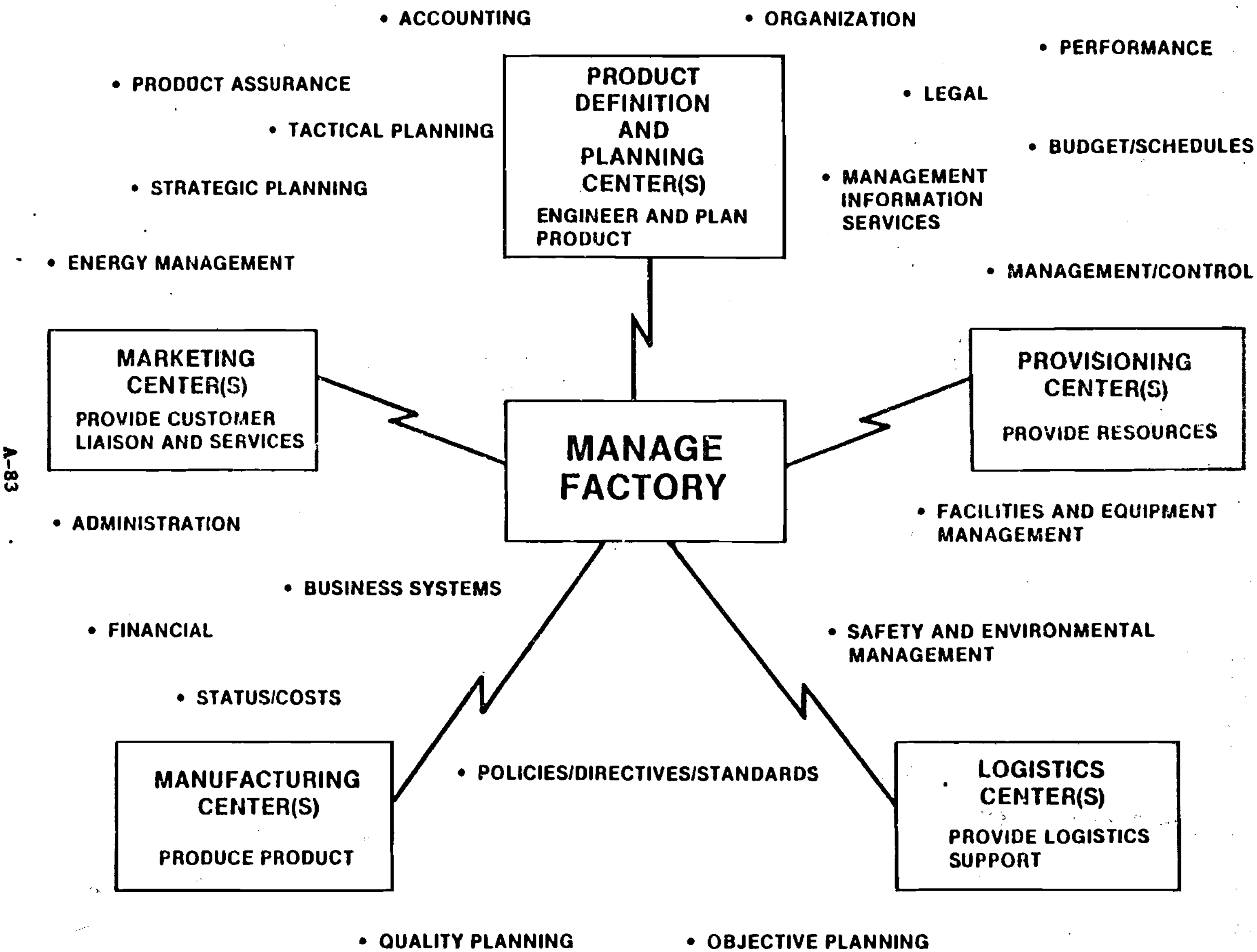
PROVIDE LOGISTICS SUPPORT
- REQUIREMENTS
- DOCUMENTS
- SPARES/KITS, ETC
- FIELD SERVICE
- MAINTENANCE
- CUSTOMER TRAINING

FOF Management

VOUGHT

- STRATEGIC PLANNING
- LABOR PRODUCTIVITY IMPROVEMENT
- EQUIPMENT PRODUCTIVITY IMPROVEMENT
- IMPROVED PRODUCT COST/ QUALITY
- IMPROVED INFORMATION FLOW
- FORECASTING
- INVENTORY CONTROL
- INFORMATION MANAGEMENT
- FINANCIAL
- COMPUTER INTEGRATED MANUFACTURING
- GROUP TECHNOLOGY
- IMPROVED DECISION MAKING
- MATERIALS REQUIREMENT PLANNING
- LEGAL
- PROJECT PLANNING
- "PAPERLESS OPERATION"
- STANDARDS/POLICY/PROCEDURES
- PROPOSAL EVALUATION/APPROVAL
- SCHEDULES & BUDGETS
- ACCOUNTING
- TACTIAL PLANNING
- SIMULATION MODELING
- OFFICE AUTOMATION
- CAPACITY PLANNING
- RESOURCE MANAGEMENT

P2-1126-25


• ACCOUNTING
• ORGANIZATION
• PERFORMANCE
• PRODUCT ASSURANCE
• LEGAL
• TACTICAL PLANNING
PRODUCT DEFINITION AND PLANNING CENTER(S)
ENGINEER AND PLAN PRODUCT
• BUDGET/SCHEDULES
• STRATEGIC PLANNING
• MANAGEMENT INFORMATION SERVICES
• ENERGY MANAGEMENT
• MANAGEMENT/CONTROL
MARKETING CENTER(S)
PROVIDE CUSTOMER LIAISON AND SERVICES
MANAGE FACTORY
PROVISIONING CENTER(S)
PROVIDE RESOURCES
• ADMINISTRATION
• FACILITIES AND EQUIPMENT MANAGEMENT
• BUSINESS SYSTEMS
• FINANCIAL
• SAFETY AND ENVIRONMENTAL MANAGEMENT
• STATUS/COSTS
MANUFACTURING CENTER(S)
PRODUCE PRODUCT
• POLICIES/DIRECTIVES/STANDARDS
LOGISTICS CENTER(S)
PROVIDE LOGISTICS SUPPORT
• QUALITY PLANNING
• OBJECTIVE PLANNING

P3-1627-1

3.10 Project 1105, Task B, Systems Requirement Document Review (Presentation)

This section contains the Task B, Systems Requirements Document presentation given by R. L. Moraski.

SYSTEM REQUIREMENTS DOCUMENT (SRD)

- DERIVED FROM NEEDS ANALYSIS
- ESTABLISHES FUNCTIONAL REQUIREMENTS
- DETAILS GENERIC NEEDS CATEGORIES
  - DESCRIPTION
  - CONCEPTS
  - EXAMPLES
  - IMPACT
- PROVIDE BASIS
  - SYSTEM SPECIFACTION
  - IMPLEMENTION STRATEGY

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INFORMATION RESOURCE MANANGEMENT (IRM)

- TIMELY AND ACCURATE INFORMATION MANDATORY
- CURRENT INFORMATION SYSTEMS GENERALLY
  - DP DEPARTMENT ORIENTED
  - DATA STRUCTURE DEPENDENT
    - ▲ INFLEXIBLE
    - ▲ MINOR CHANGES=MASSIVE MODIFICATION
  - HARDWARE DEPENDENT
  - NOT USED EFFECTIVELY
- KEY TO INTEGRATION AND MFG FLEXIBILITY

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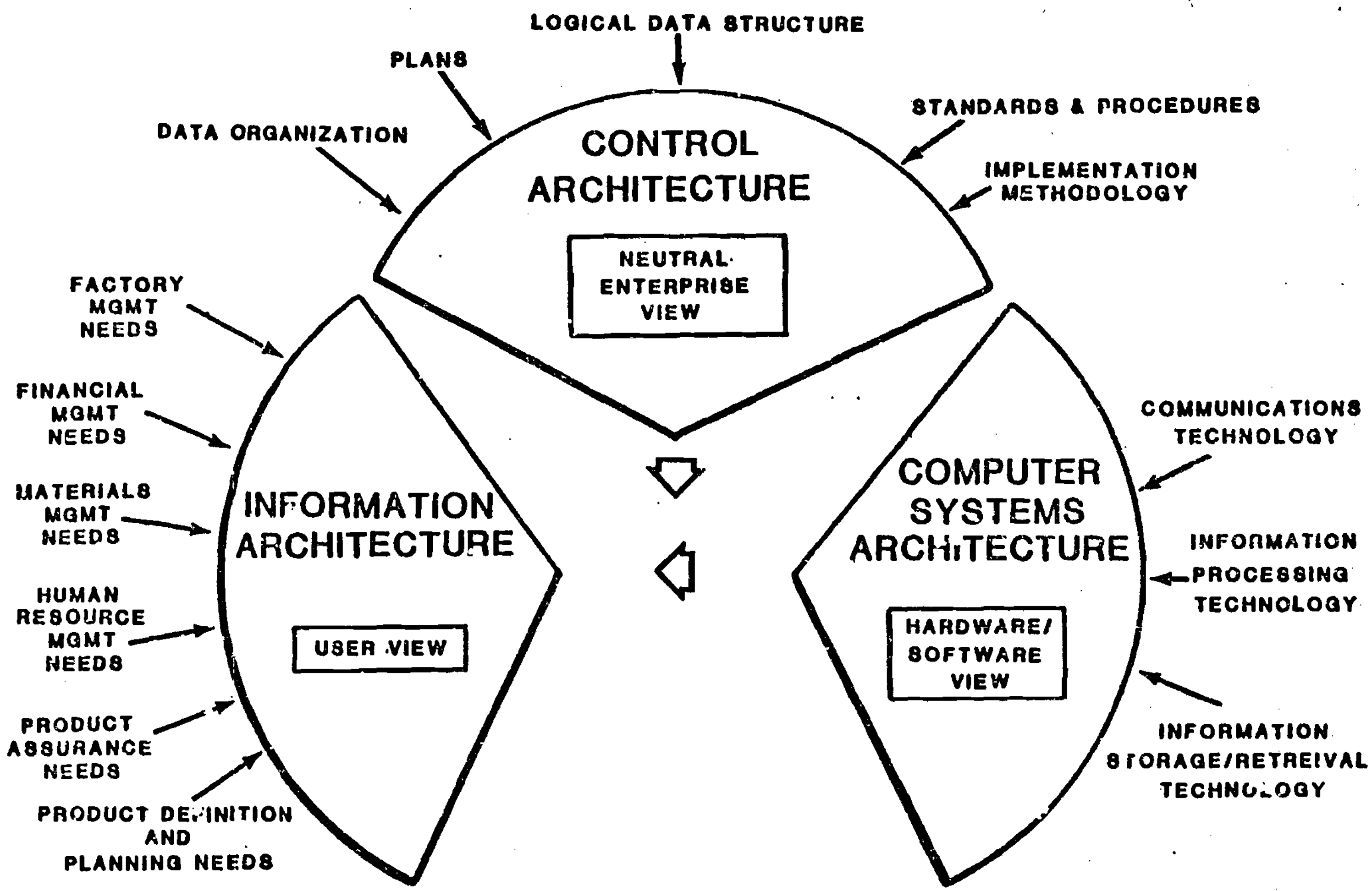
IRM CONCEPTS

- FUNDEMENTAL FOF BUILDING BLOCK
  - LOGICAL COMMON FACTORY DATA BASE
    - ▲ DISTRIBUTED
    - ▲ CENTRAL
  - NEUTRAL DATA STRUCTURE/COMMON DATA MODEL
  - HARDWARE INDEPENDENCE
  - RAPID DATA CHANGE
    - ▲ USER
    - ▲ WITHOUT SOFTWARE MODIFICATION
- FACTORY WIDE COMMUNICATIONS NETWORK
- USER DEVELOPED INFORMATION
- DESIGN TO MEET USER REQUIREMENTS



THREE ARCHITECTURE APPROACH

IRM IMPACT

- AFFECTS VIRTUALLY EVERY FUNCTION
- REQUIRED INFORMATION TO ALL USERS
  - WHEN NEEDED
  - IN FORM NEEDED
- IMPACT ON MANAGEMENT
  - BETTER COMMUNICATION
  - PROVIDE DECISION SUPPORT TOOLS & INFORMATION
  - SOFT ALLOCATION OF RESOURCES (MATRIX MGMT)
  - MANAGE AND CONTROL CO. KNOWLEDGE
  - GREATER ORGANIZATIONAL FLEXIBILITY
- IMPACT ON HUMAN RESOURCES
  - JOB ELIMINATION
  - JOB CREATION
  - NEW SKILLS & JOB ROLES

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MANAGE FACTORY

- OBJECTIVE: IMPROVE PRODUCTIVITY
- THREE THINGS WORK AGAINST
  - REWARD SYSTEM
    - ▲ YEARLY GOALS
    - ▲ QUARTERLY EMPHASIS
- SHORT TERM OUTLOOK
- HIERARCHIAL ORGANIZATIONAL STRUCTURE
  - FOSTERS AUTHORITARIAN PEOPLE MGMT
    - ▲ PEOPLE COGS IN VAST MACHINE
    - ▲ LOSING EFFECTIVENESS
  - NEED MORE PARTICIPATIVE APPROACH

MANAGE FACTORY CONCEPTS

- INSEPARABLE FROM IRM
- INFORMATION INTEGRITY VITAL
  - PLAN
  - CONTROL
  - DIRECT
- INCLUDES
  - TECHNOLOGY ASSESSMENT
  - IMPLEMENTATION
  - MANAGEMENT OF CHANGE
  - PRODUCT QUALITY
  - PRODUCTIVITY
  - LONG RANGE PLANNING
    - ▲ WHAT PRODUCT/PRODUCTS
    - ▲ FACILITIES
    - ▲ PERSONNEL

MANAGE FACTORY IMPACT

- FINANCIAL IMPLICATIONS
  - COST ACCOUNTING
  - ROI/ROA EMPHASIS
- CULTURAL ASPECTS (ALL LEVELS)
  - PERSONNEL
  - ORGANIZATION
  - WORK ENVIRONMENT
- PRODUCE PRODUCT AND ASSURE
  - REASONABLE CUSTOMER COST
  - PROFIT
  - COMPANY LONGEVITY
- IMPROVED COORDINATION THROUGH INTEGRATION
- IMPROVED DECID DECISION MAKING

PRODUCT DEFINITION & PLANNING (PDP)

- COMBINES INTERACTIVE DEPENDENT ENGINEERING FUNCTIONS
  - DESIGN
  - MANUFACTURING
  - TOOL, ETC.
- PRODUCT DESIGN
  - GEOMETRY
  - ENGINEERING ANALYSIS
  - NON-GEOMETRIC DATA
- MANUFACTURING PLANNING
  - PROCESS PLANS
  - TOOL PLANS
  - QUALITY PLANNING
  - PRODUCTION PLANNING
- FACILITIES DESIGN
- PLANT LAYOUT

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PDP CONCEPTS

- DESIGN FOR
  - COST
  - PRODUCIBILITY
  - QUALITY
- REDUCTION OF ECO'S
- REDUCE LEAD TIME
- DESIGN TO PROCESS VIA COMPUTER

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PDP REQUIREMENTS

- REDEFINE EXECUTIVE RESPONSIBILTY
- COMPUTER GRAPHICS
- SOLID MODELING
- PRE-PRODUCTION MFG "PROOFING"
  - MFG PLANS
  - TOOLS
  - PRODUCTION SPECS
  - SET-BACKS, ETC,
- GROUP TECHNOLOGY
- GENERATIVE PROCESS PLANNING
- ON-LINE PERFORMANCE STATUS

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PRODUCT ASSURANCE (PA)

- QUALITY IS EVERYONE'S RESPONSIBILITY
- GUS SCHRADER, VP MFG, TRW, (AM JAN 83)
  - "WE EXCEL AT SCRAPPING BURNT TOAST"
  - "STATUS QUO UNACCEPTABLE"
  - "CREATE AWARENESS FROM CEO ON DOWN"
  - "PLAN FOR QUALITY"
  - "FASTEST TRACK TO PRODUCTIVITY"
- QUALITY OR PRODUCTION
  - NO LONGER A CHOICE
  - MUST HAVE BOTH
- DESIGN AND BUILD IN
  - CAN NO LONGER AFFORD TO INSPECT IN

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PA CONCEPTS

- INFORMATION IS THE KEY TO QUALITY
- REQUIREMENTS FOR QUALTITY QUALITY MUST BE INTEGRATED
- IMPROVE TI&E METHODS
  - STATISICAL QUALITY CONTROL – DEMING
  - NON-DESTRUCTIVE TESTING
- IMPROVED QUALITY INFORMATION
  - INTERNAL
  - EXTERNAL
  - VENDORS
  - SUBCONTRACTORS
  - CUSTOMER
- IMPROVED QUALITY IN
  - SOFTWARE – EQUIPMENT – PROCESS
  - HARDWARE – PRODUCT
- LEAD TO IMPROVED PRODUCTIVITY

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HUMAN RESOURCE MANAGEMENT (HRM)

- CULTURAL ASPECTS VITAL
  - WORK ENVIRONMENT
  - PERSPECTIVE OF COMPANY AND MANAGEMENT
- FOF WILL (AT ALL LEVELS)
  - REQUIRE GREATER INVOLVEMENT OF
    - ▲ MANAGEMENT
    - ▲ STAFF
  - CHANGE ORGANIZATIONS
  - CHANGE PHYSICAL LAYOUT
  - CHANGE JOB CONTENT
  - REQUIRE DIFFERENT SKILL AND JOB KNOWLEDGE
- RESOLUTION OF HRM PROBLEMS IN FOF COULD BE MORE VITAL THAN SOLUTION OF TECHNICAL PROBLEMS!

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HRM CONCEPTS

- MUST RESOLVE CULTURAL ASPECTS
  - TO GAIN ACCEPTANCE OF FOF
  - STIMULATE SUPPORT AT ALL LEVELS
- EXTENSIVE RETRAINING REQUIRED
  - IN HOUSE
  - UNIVERSITY
  - TECHNICAL SCHOOL
- USE OUR HUMAN RESOURCE RESOURCE MORE EFFECTIVELY
  - NEW INCENTIVES AND MOTIVATION
  - LONG RANGE PLANNIN FOR PERSONNEL REQUIREMENTS

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MATERIALS MANAGEMENT (MM)

- PROCUREMENT
- STORAGE
- MOVEMENT
- ALLOCATION
  - RAW MATERIALS
  - COMPONENTS
  - WORK-IN-PROCESS
  - TOOLS
  - EQUIPMENT
  - FACILITIES
- INCLUDES
  - SUBCONTRACTOR SUPPLIED COMPONENTS
  - GFE

MM

- 40-60% WEAPON SYSTEM-SUBCONTRACTED
- 15-25% GFE
- INVENTORY CARRYING COSTS
- MATERIAL QUALITY
- MATERIAL DELIVERY
- INTERNAL MATERIAL HANDLING

MM CONCEPTS

- IMPROVED SUBCONTRACTOR AND VENDOR INTERFACE
  - RIGHT AMOUNT
  - RIGHT PLACE
  - RIGHT TIME
  - APPROPRIATE QUALITY
  - STABILIZED PRICE
- AUTOMATED MATERIAL HANDLING
- ENHANCED INVENTORY CONTROL
- IMPROVED WORK-IN-PROCESS MANAGEMENT

FINANCIAL MANAGEMENT (FM)

- PROFITABILITY IS KEY GOAL OF BUSINESS -- FOT OR FOF
- FINANCE IS THE EQUALIZER IN EVALUATING ALL FUNCTIONS
- FINANCIAL STRUCTURE IS NOT A MATCH WITH PROCESSES
- FOCUS IS ON SHORT-TERM PROFITABILITY
- FOF MUST BETTER USE FM IN AN INTEGRATED SETTING

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FM CONCEPTS

- REAL TIME FEEDBACK
  - COST
  - PERFORMANCE
  - PRODUCTIVITY
- IMPROVED INVENTORY COST MEASUREMENT
- INTEGRATION OF FINANCIAL SYSTEM WITH OTHER FACTORY SYSTEMS
  - PRODUCTION CONTROL
  - MANAGEMENT CONTROL
  - MATERIAL CONTROL, ETC.
- IMPROVED BUDGET PLANNING
- IMPROVED FINANCIAL FORECASTING
- IMPROVED ROI/ROA ANALYSIS

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- EMPHASIS ON LONG TERM COMPANY VIABILITY
  - TECHNOLOGY ACQUISITION
  - STRATEGIC ISSUES
  - LESS SHORT TERM EMPHASIS
- FACTORY WIDE DATA BASE IS KEY TO FINANCIAL INTEGRATION

FM IMPACT

- KNOW FACTORY STATUS -- MANAGE ACCORDINGLY
- KNOW TRUE COSTS, BOTTLENECKS, INEFFICIENCIES
- OPTIMIZE INTEGRATED FACTORY FUNCTIONS
- ORIENT TO LONG-TERM VIABILITY, PROFITABILITY AND COMPETITIVENESS
- FACTORY WILL BE A SINGLE COHESIVE UNIT

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3.11 Project 1105, Task B, Needs Analysis Review (Presentation)

This section contains the Task B, Needs Analysis presentation given by A. Wayne Snodgrass.

ICAM PROJECT PRIORITY 1105
ESTABLISHMENT OF THE FACTORY OF THE FUTURE FRAMEWORK

TASK B
REVIEW TEAM
NEEDS ANALYSIS REVIEW

4-5 MAY, 1983

DAYTON, OHIO

BY

A. W. SNODGRASS
D. APPLETON COMPANY, INC.

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29 June 1984

PRESENTATION OBJECTIVES

- ESTABLISH BASIS FOR ANALYSIS
- ASSESS TASK RESULTS AND IDENTIFY
  - AREAS OF AGREEMENT
  - AREAS OF CONCERN
  - REQUIRED ADDITIONAL AREAS
- REVIEW TEAM SUGGESTIONS

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APPROACH

- BACKGROUND
- NEEDS ANALYSIS DOCUMENT (NAD) FORMAT
  - ICAM DOCUMENTATION STANDARDS
  - PROJECT PRIORITY 1105 NAD
- AEROSPACE MEMBERS TEST APPROACH
- REVIEW OF NAD

APPROACH

- BACKGROUND
- NEEDS ANALYSIS DOCUMENT (NAD) FORMAT
  - ICAM DOCUMENTATION STANDARDS
  - PROJECT PRIORITY 1105 NAD
- AEROSPACE MEMBERS TEST APPROACH
- REVIEW OF NAD

FoF Conceptual Framework Effort Relationship to ICAM Life Cycle

	ICAM LIFE CYCLE							
	NEEDS ANALYSIS	REQUIREMENTS DEFINITION	PRELIMINARY DESIGN	DETAIL DESIGN	CONSTRUCTION & VERIFICATION TEST	INTEGRATION VALIDATION & TEST	IMPLEMENT AND USE	MAINTAIN AND SUPPORT
TASK B DELIVERABLE	UNDERSTAND PROBLEM		FORMULATE AND JUSTIFY SOLUTION		BUILD AND INTEGRATE SOLUTION		IMPLEMENT AND MAINTAIN SOLUTION	
SCOPING DOCUMENT (SD)	X							
NEEDS ANALYSIS DOCUMENT (NAD)	X							
STATE OF-THE ART DOCUMENT (SAD)	X							
SYSTEMS REQUIREMENTS DOCUMENT (SRD)		X						
SYSTEM SPECIFICATION (SS)			X					

NOTE: THIS FIGURE SHOWS THE RELATIONSHIP OF THE TASK "B" ESTABLISH FACTORY OF THE FUTURE CONCEPTUAL FRAME WORK DELIVERABLES TO THE ICAM LIFE CYCLE. THIS MATRIX IS OFFERED TO CLARIFY PRECISELY WHAT TASK "B" WILL AND WILL NOT PROVIDE. SPECIFICALLY, THERE WILL BE ONLY A CONCEPTUAL DESIGN (THE FRAMWORK) FOR THE FACTORY OF THE FUTURE PRODUCED. ALL EFFORTS IN THIS TASK ARE AIMED AT A CONCEPTUAL FRAMEWORK, NOT A DETAIL DESIGN FOR THE FACTORY OF THE FUTURE.

NEEDS ANALYSIS PER SOW

PURPOSE: IDENTIFY THE PROBLEMS TO BE ADDRESSED BY THE CONCEPTUAL FRAMEWORK

REQUIREMENTS:

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- RELATE "BOTTOM-UP" NEEDS TO "TOP-DOWN" GOALS
- FROM INTEGRATED FACTORY VIEW
- CONTEXT DEFINED FROM MFG-0,1 & DES-0,1
- FOLLOW DOC. STDS.

"A NEED IS A STATEMENT OF DEFICIENCY OR VOID IN AN EXISTING MANUFACTURING SYSTEM."

TERMS AND ABBREVIATIONS

- FACTORY
- FACTORY OF THE FUTURE (FoF)
- FoF CONCEPTUAL FRAMEWORK
- FoF IMPLEMENTATION STRATEGY
- GOAL
- NEED
- IMPROVEMENT CONCEPT

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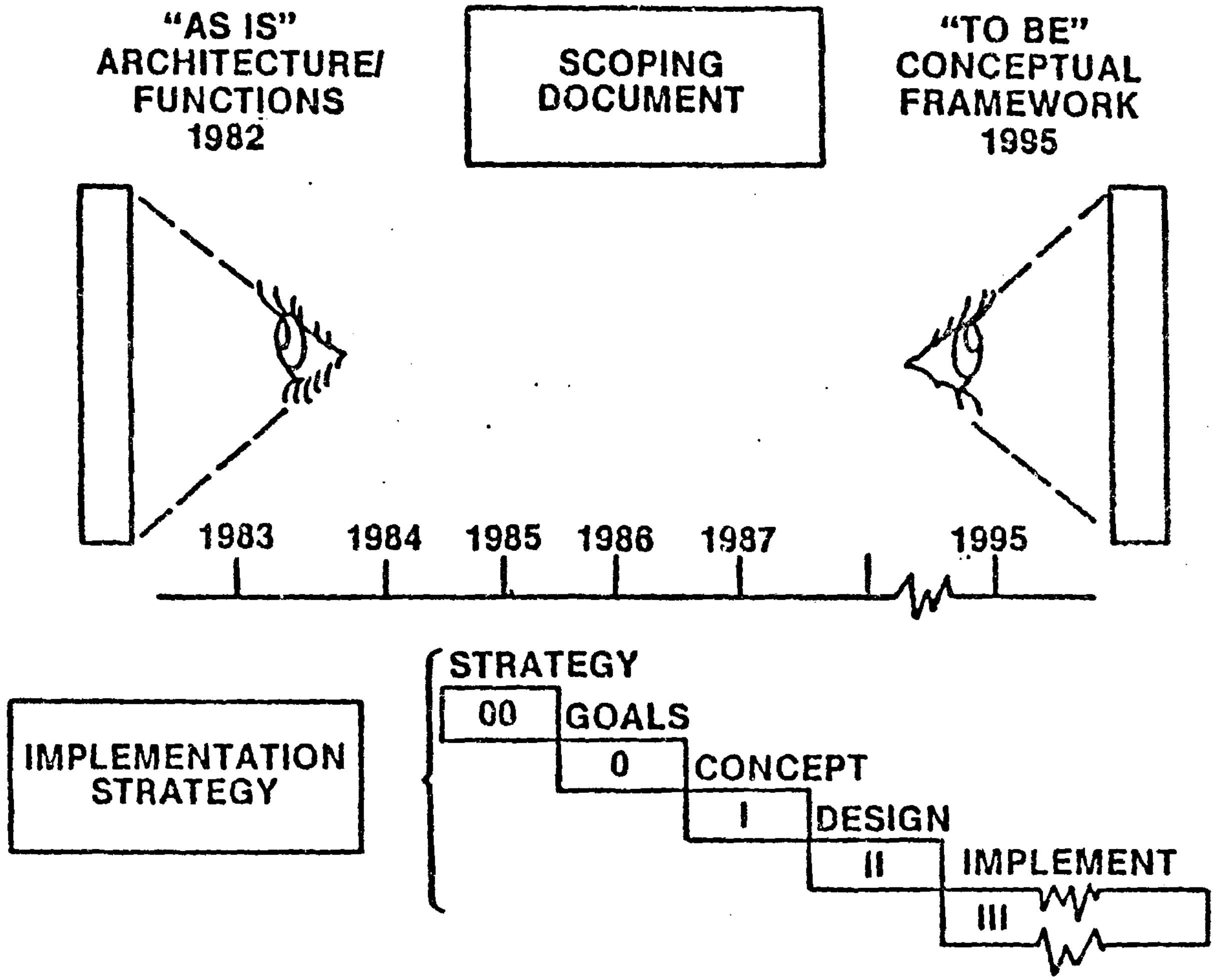
COALITION TASK



REF: FIG 3-3 PG 5

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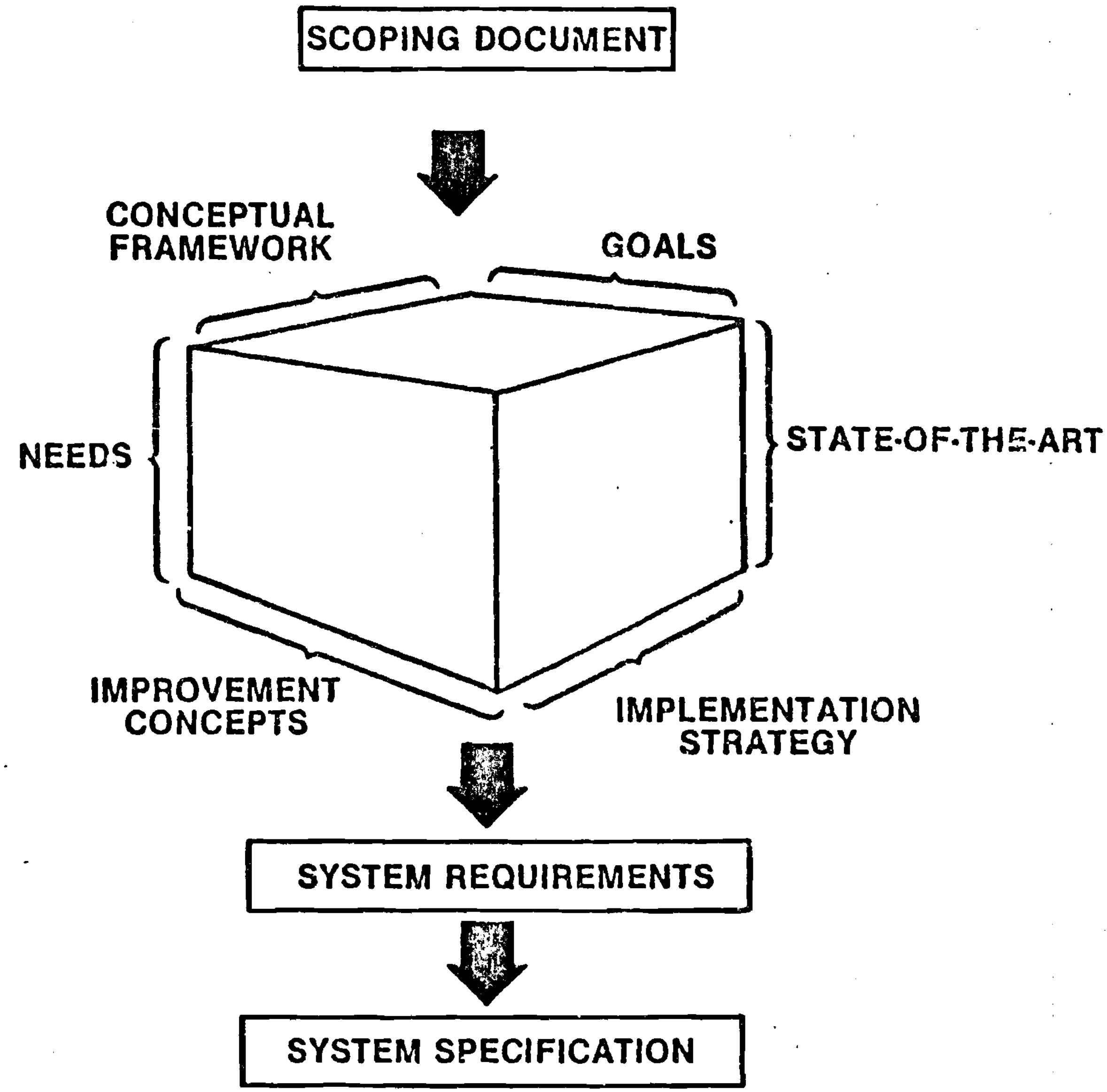

REF: FIG 3-4 PG 3-6

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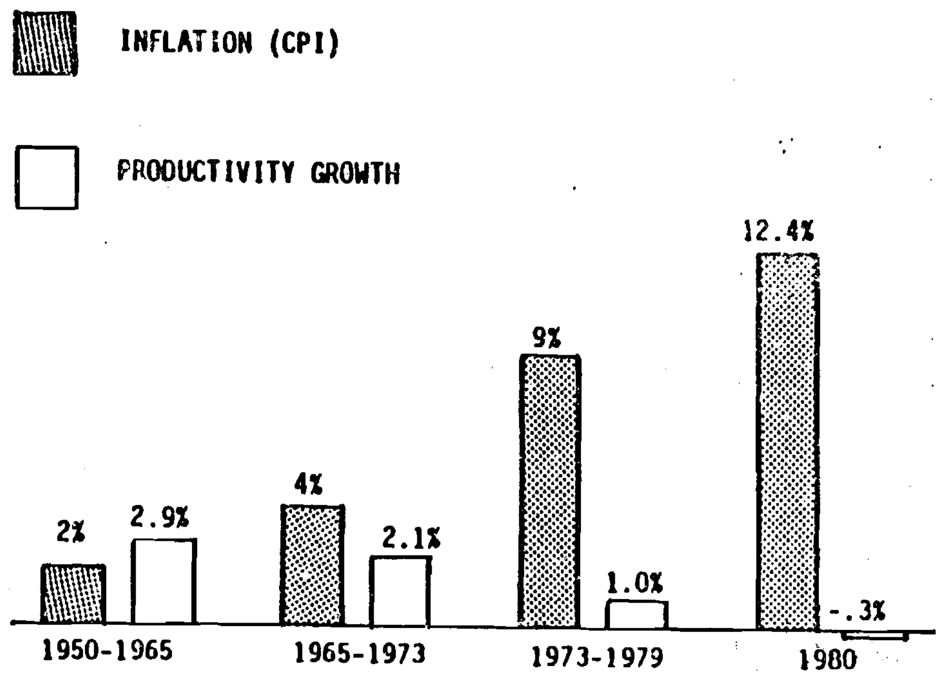
INFLATION vs U.S. PRODUCTIVITY GROWTH



SOURCE: U.S. BUREAU OF LABOR STANDARDS (BLS)

FIGURE A-1 PG A-1

RATIO OF INVESTMENT TO GNP vs PRODUCTIVITY GROWTH

(MANUFACTURING 1960-1977)

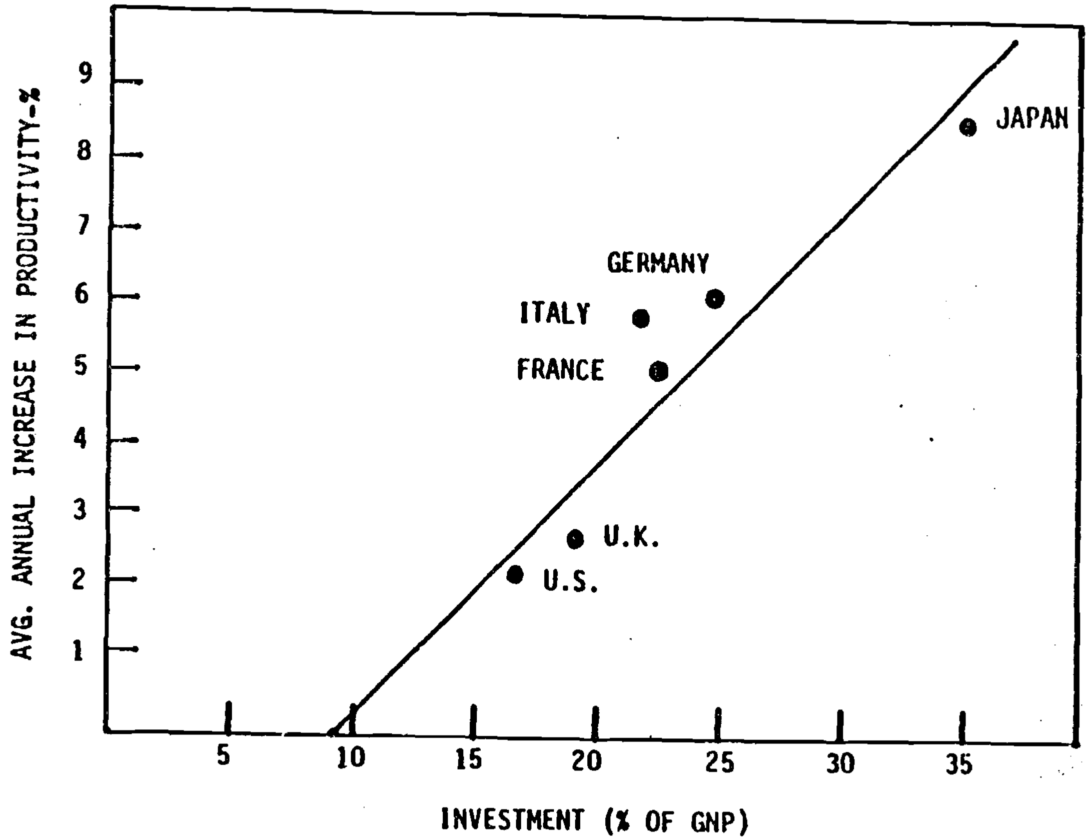


FIGURE A-2 PG A-2

PRODUCTIVITY FORMULAS

FORMULA 1: $$\text{PRODUCTIVITY} = \frac{\text{OUTPUT (\$)}}{\text{INPUT (\$)}}$$

FORMULA 2: $$\text{PRODUCTIVITY} = \frac{\text{SELLING PRICE (\$)}}{\text{TOTAL COST (\$)}}$$

FORMULA 3: $$\text{PRODUCTIVITY} = \frac{\text{SELLING PRICE}}{\underset{\text{LABOR}}{\text{DIRECT (\$)}} + \underset{\text{LABOR}}{\text{INDIRECT (\$)}} + \underset{\text{(DIR. \& IND.}}{\text{MATERIAL (}}}$$

GOAL: GOAL #1 REDUCE ANY OF THE COSTS WHILE HOLDING PRICE CONSTANT.

GOAL #2 REDUCE FLOW THROUGH TIME FOR ANY COST ITEM.

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OBJECTIVE: CONVERT CAPITAL TO RESOURCES; RESOURCES TO PRODUCTS; PRODUCTS TO REVENUE (REVENUE MINUS COST EQUALS PROFIT); PROFIT TO CAPITAL.

RESULT: PRODUCTIVITY IS IMPROVED BY RAPID CONVERSION OF CAPITAL TO PROFIT AND BACK AGAIN TO CAPITAL.

23 JUNE 1984

FIGURE A-3 PG A-3

APPENDIX A – DETAILED FoF GOALS DISCUSSION

- REDUCE COST/PRICE & INCREASE PROFITS
- IMPROVE QUALITY
- IMPROVE HUMAN RESOURCE MANAGEMENT
- REDUCE LEAD TIME
- IMPROVE MANUFACTURING FLEXIBILITY

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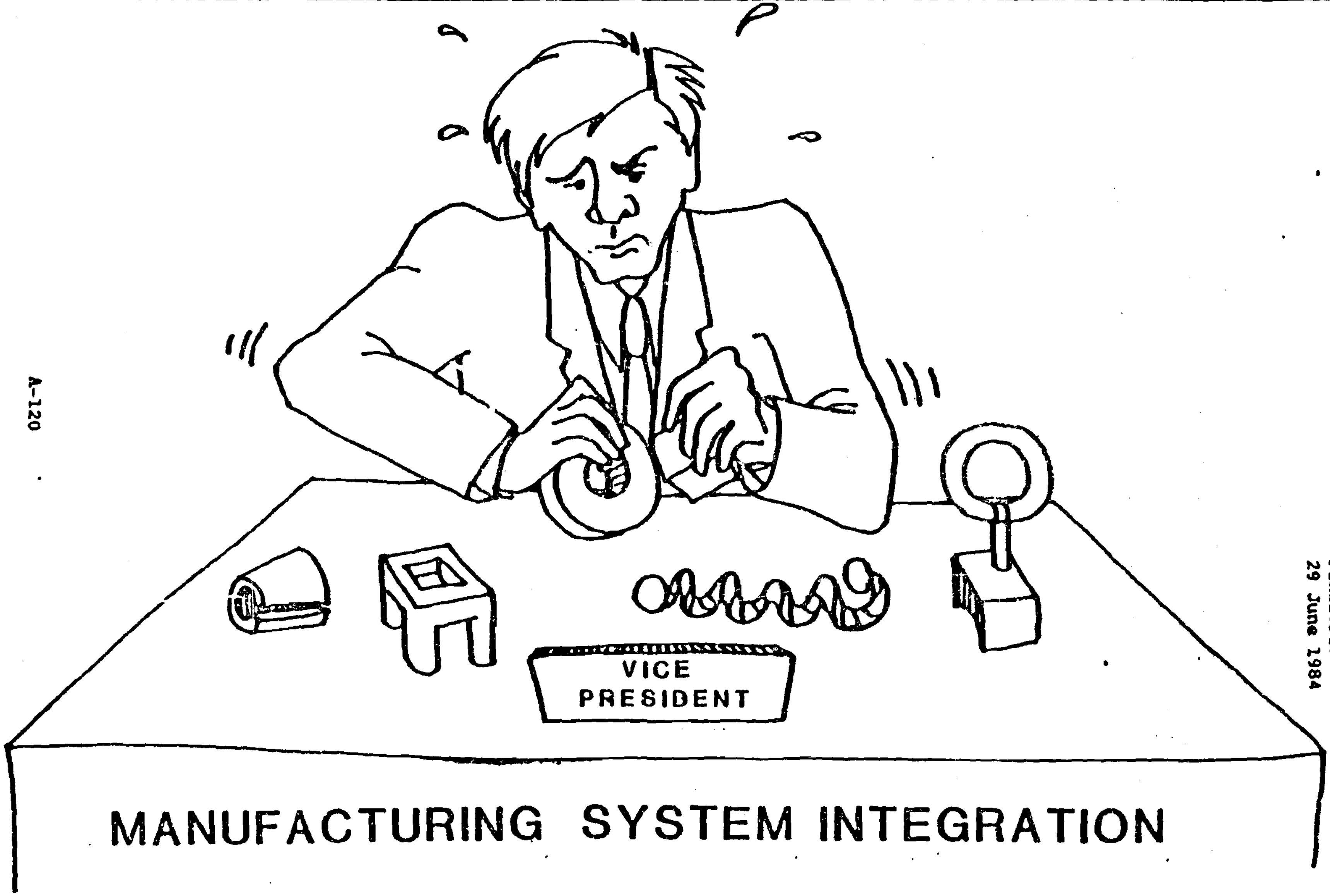
COMPUTER INTEGRATED MANUFACTURING



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SOLUTION - CIM

INTEGRATION:

- **FORMING INTO A WHOLE**
- **SHARE A COMMON COMPONENT**
  - **PHYSICAL INTEGRATION**
  - **INFORMATION INTEGRATION**

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COMPUTER INTEGRATED MANUFACTURING

- MANUFACTURING, WHICH BEGINS WITH PRODUCT DESIGN AND ENDS WITH SUPPORT AND MAINTENANCE IN THE FIELD, IS A MONOLITHIC, INDIVISIBLE FUNCTION. --- <u>NO PART CAN BE SUCCESSFULLY CONSIDERED IN ISOLATION FROM ALL OTHER PARTS.</u>

- DIVERSE AS THE VARIOUS PARTS OF MANUFACTURING MAY SEEM, THERE IS A <u>COMMON THREAD</u> THAT RUNS THROUGH THE FULL SCOPE OF ALL MANUFACTURING ACTIVITIES. -- MANUFACTURING IS, IN THE ULTIMATE ANALYSIS, <u>A SERIES OF DATA PROCESSING OPERATIONS.</u>

DR. JOSEPH HARRINGTON
1980 CAD/CAM CONFERENCE

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CHANGING THE FOCUS

- EMPHASIZE INTEGRATION OF MANUFACTURING ACTIVITY VERSUS SPECIALIZATION.
- REFOCUS MANAGEMENT ATTENTION FROM MANUFACTURING TECHNIQUES TO MANUFACTURING SYSTEMS.
- FACE AND RESOLVE NEED FOR MANAGEMENT ORGANIZATION RESTRUCTURING

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JIM LARDNER
DEERE&CO.

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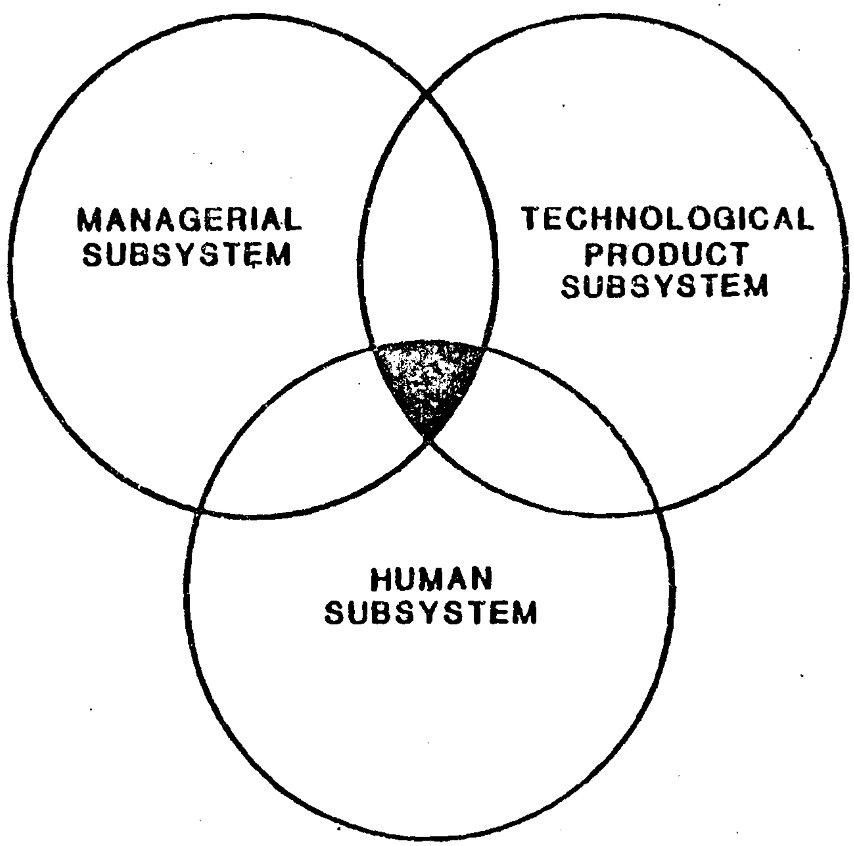
RESOURCE MANAGEMENT

CAPITAL RESOURCES

TIME RESOURCES



HUMAN RESOURCES

INFORMATION RESOURCES

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INFORMATION RESOURCE MANAGEMENT (IRM)

"INFORMATION IS THE MANAGER'S MAIN TOOL, INDEED THE MANAGER'S "CAPITAL", AND IT IS HE WHO MUST DECIDE WHAT INFORMATION HE NEEDS AND HOW TO USE IT."

PETER DRUCKER–"MANAGING THE INFORMATION EXPLOSION"

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INFORMATION RESOURCE AND HUMAN RESOURCE MANAGEMENT

- THE PRODUCT OF ANY EMPLOYEE THAT DOES NOT LAY HANDS ON THE HARDWARE PRODUCT IS DATA AND/OR DECISIONS.
- EMPLOYEE "PARTICIPATION" IS DEPENDENT UPON KNOWLEDGE OF THEIR SURROUNDING ENVIRONMENT AND CONTRIBUTION OF THEIR DATA.
- TEAM MANAGEMENT TECHNIQUES OFFER AN EXPLOSIVE IMPACT ON PRODUCTIVITY
- TMT STRUCTURED METHODOLOGIES CHANNEL THIS ENERGY TOWARD "TOP DOWN" PLANNING GOALS

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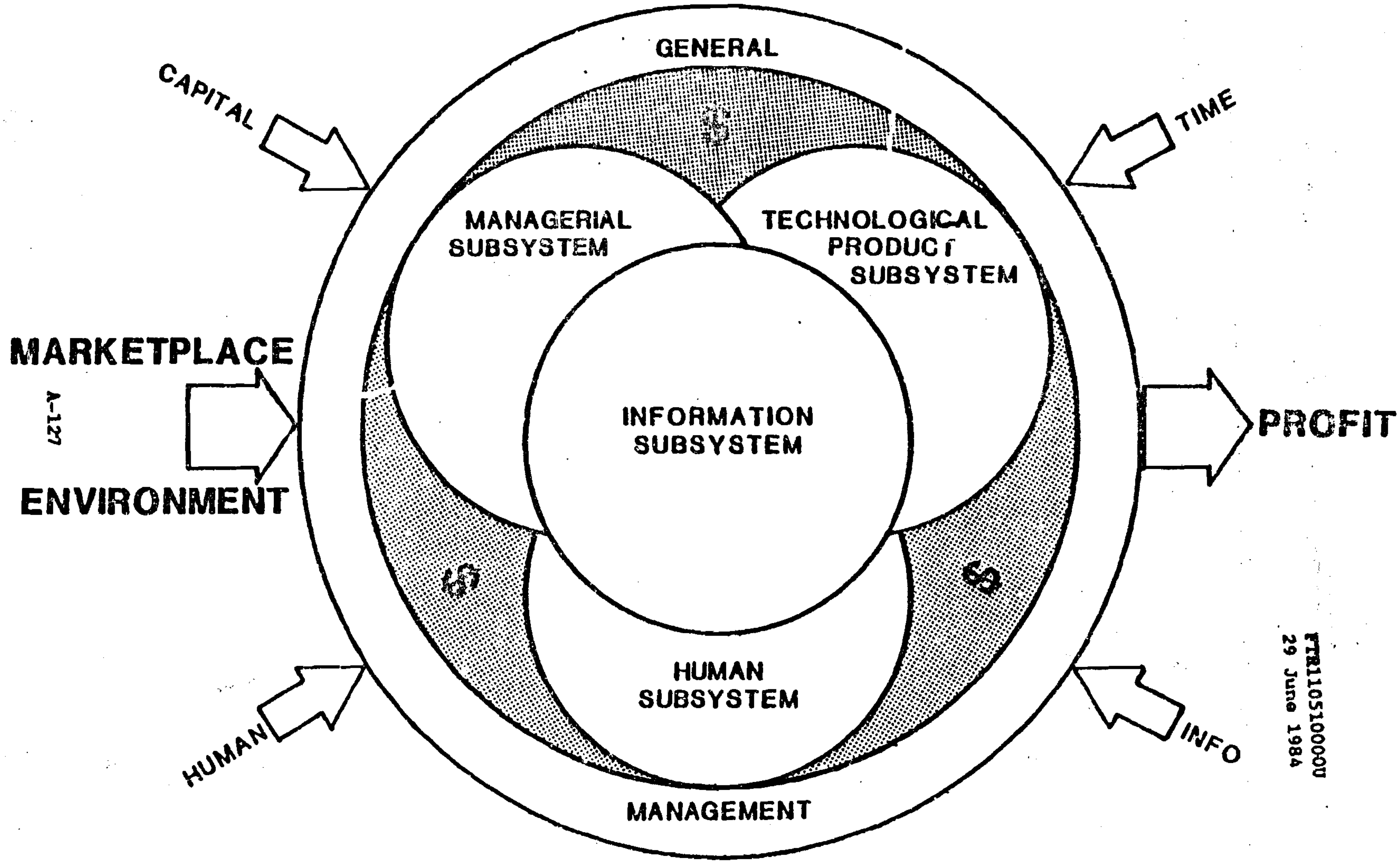
INFORMATION RESOURCE MANAGEMENT



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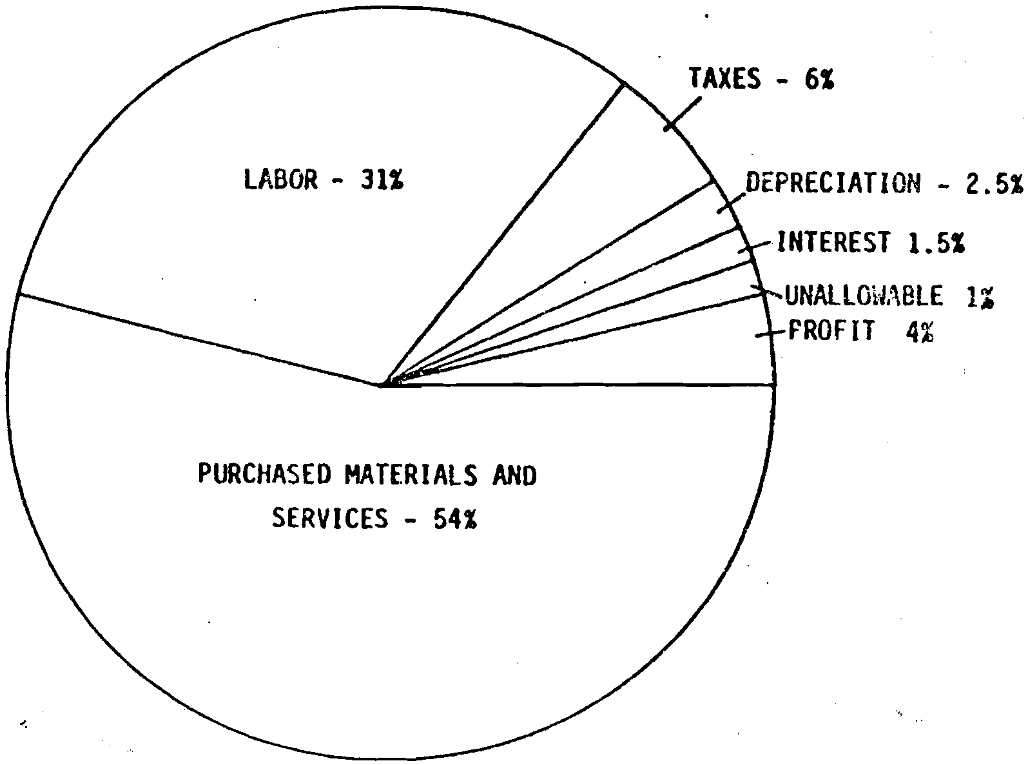
FoF FINANCIAL MODEL



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NAD FORMAT/ICAM DOCUMENTATION STANDARDS

TABLE OF CONTENTS

PERSPECTIVE: AN APPLICATION SYSTEM IN TODAY'S ENVIRONMENT.

NEEDS ANALYSIS DOCUMENT

TABLE OF CONTENTS

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NEEDS ANALYSIS DOCUMENT (cont'd)

TABLE OF CONTENTS

AEROSPACE MEMBERS TEST APPROACH

- COALITION – FRAMEWORK "STORYBOARDING"
- MANAGERIAL AND TECHNICAL INTERVIEWS
- NEEDS/OPPORTUNITIES FOR IMPROVEMENT
- IMPROVEMENT CONCEPTS REQUIRED
- ENABLING TECHNOLOGY REQUIRED

AEROSPACE MEMBERS TEST APPROACH (cont'd)

- **IMPROVEMENT CONCEPTS ANALYSIS BASELINE**
  - **MANTECH**
  - **ICAM**
  - **TECH MODS**
  - **AEROSPACE**
  - **COMMERCIAL**

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FoF NEEDS

- TWO HUNDRED INITIALLY IDENTIFIED (200)
- THIRTY SEVEN MAJOR AREAS (37)
- SEVEN NEEDS CATEGORIES

NEEDS ANALYSIS RESULTS

- **REDUCE PRODUCT COST AND LEAD TIME**
  - MARKETING
  - MANAGING
  - DESIGN AND ENGINEERING
  - PROVISIONING
  - PRODUCTION
  - LOGISTICS
- **IMPROVED FACTORY INFORMATION MANAGEMENT AND COMMUNICATION**
  - FASTER, MORE ACCURATE INFORMATION FLOW
  - GREATER USE OF COMMON INFORMATION
  - IMPROVED USER ACCESS TO REQUIRED INFORMATION
  - IMPROVED INTEGRITY OF INFORMATION
  - IMPROVED DEFINITION OF RESOURCE REQUIREMENTS
  - BETTER INFORMATION ON RESOURCE USE

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NEEDS ANALYSIS RESULTS (cont'd)

- IMPROVED FLEXIBILITY AND RESPONSIVENESS

- IMPROVED MANAGEMENT
  - INCREASED JOB SATISFACTION
  - BETTER USE OF PERSONNEL SKILLS
  - MORE EFFICIENT USE OF RESOURCES
  - MORE EFFICIENT MANAGEMENT OF
    - PROPOSALS
    - MATERIAL FLOW
    - MAINTENANCE
    - TRAINING
  - CLOSER COORDINATION OF SCHEDULES AND PRIORITIES
  - IMPROVED TRANSLATION OF STRATEGIC BUSINESS PLANS
    - TACTICAL & OPERATIONAL PLANS

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NEEDS ANALYSIS RESULTS (cont'd)

- MORE CONSISTENCY WITH BUSINESS PLANS

- IMPROVED FINANCIAL MANAGEMENT METHODS
  - ROI AND ROA ANALYSIS
  - IMPROVED COST TRACKING
  - IMPROVED BUDGET PLANNING AIDS
  - IMPROVED FORECASTING METHODS
- IMPROVED MANAGEMENT OF TECHNOLOGICAL CHANGE
  - BETTER TECHNOLOGY IDENTIFICATION
  - IMPROVED METHODS OF EVALUATION
  - IMPROVED PLANNING
  - IMPROVED CONTROL OF IMPLEMENTATION
- BETTER PRODUCT ASSURANCE INTEGRATION AND OPTIMIZATION
- IMPROVED DECISION SUPPORT
  - BETTER METHODS TO IDENTIFY REQUIREMENTS

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NEEDS ANALYSIS RESULTS (cont'd)

- BETTER SIMULATION TOOLS
- BETTER OPERATIONS RESEARCH TOOLS
- BETTER EVALUATION CONCEPTS

- IMPROVED HUMAN RESOURCE MANAGEMENT

  - BETTER ORGANIZATIONAL PLANNING
  - BETTER USE OF HUMAN RESOURCES
  - GREATER JOB SATISFACTION AND MOTIVATION
  - LONG TERM MEASUREMENT AND REWARD SYSTEM
  - BETTER RECRUITING
  - BETTER ORIENTATION AND TRAINING
  - BETTER CAREER DEVELOPMENT

- IMPROVED FUNCTIONAL OUTPUT

  - MARKETING

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NEEDS ANALYSIS RESULTS (cont'd)

- PROPOSALS
- MARKET INTELLIGENCE

\- PRODUCT DEFINITION AND PLANNING

- IMPROVED PRODUCT DESIGNS
- IMPROVED MANUFACTURING PLANS
- IMPROVED EQUIPMENT AND FACILITIES DESIGN

\- PROVISIONING

- BETTER FACILITIES
- BETTER EQUIPMENT
- BETTER TOOLS
- BETTER MATERIALS
- GREATER FLEXIBILITY
- PRODUCT CHANGE
- PROCESS CHANGE

NEEDS ANALYSIS RESULTS (cont'd)

- MANUFACTURING
  - PRODUCT QUALITY
  - SCHEDULE PERFORMANCE
- LOGISTICS
  - CUSTOMER SUPPORT
  - CUSTOMER TRAINING
  - KITS AND SPARES

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SEVEN NEEDS CATEGORIES

- INFORMATION RESOURCE MANAGEMENT
- MANAGEMENT
- PRODUCT DEFINITION AND PLANNING
- PRODUCT ASSURANCE
- HUMAN RESOURCE MANAGEMENT
- MATERIALS MANAGEMENT
- FINANCIAL MANAGEMENT

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IMPLEMENTATION STRATEGY

- FoF MANAGEMENT
  - CONCEPTS
  - OBJECTIVES
  - CONTROLS
- AVAILABLE TECHNOLCGIES
  - WHEN USED
  - LOGICAL IMPLEMENTATION SEQUENCE
- PHYSICAL FACTORY RESOURCES
  - LIMITATIONS
  - OPPORTUNITIES
- COMMUNICATION AND INFORMATION MANAGEMENT
  - NEW CONCEPT IMPLEMENTATION
  - AFFECT ON FACTORY

REF: 3.3 PG 3-17

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IMPLEMENTATION STRATEGY (cont'd)

- FINANCIAL MANAGEMENT
  - NEW ACCOUNTING METHODS
  - DIRECTION AND CONTROL
- FUNCTIONS/ACTIVITIES
  - WHAT WILL BE ADDED, DELETED OR CHANGED
  - HOW SHOULD OLD BE PHASED OUT AND NEW PHASED IN
- ORGANIZATION STRUCTURE
  - NEW TECHNOLOGY APPLICATION CHANGED
  - HUMAN SKILL REQUIREMENT CHANGES

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NEEDS NOT ADDRESSED

- **ENVIRONMENTAL CONDITIONS**
  - TECHNOLOGICAL
  - ECONOMIC
  - REGULATION
  - PHYSICAL ENVIRONMENT
  - MARKET
- **MANAGEMENT STYLE**
  - REQUIRED CHANGES
  - IMPLEMENTATION STRATEGY

REF: 3.4 PG 3-20

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NEEDS ANALYSIS CONCLUSIONS

- INFORMATION RESOURCE MANAGEMENT (IRM) AND INFORMATION TECHNOLOGY ESSENTIAL
- MANAGEMENT AND IRM SEPARATION IMPOSSIBLE
- ENGINEERING FUNCTION COMBINATION ESSENTIAL
- QUALITY IS PRODUCTIVITY FAST TRACK
- CULTURAL CHANGE MANAGEMENT VITAL
- MATERIALS MANAGEMENT CRITICAL
- DIRECT vs INDIRECT MANAGEMENT CRITICAL

REF: 3.7 PG 3-35

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3.12 Project 1105, Task B, State-of-the-Art Review (Presentation)

This section contains the Task B, State-of-the-Art Document presentation given by R. L. Diesslin.

A-147

ICAM PROJECT PRIORITY 1105

ESTABLISHMENT OF THE FACTORY OF THE FUTURE FRAMEWORK

STATE-OF-THE-ART DOCUMENT REVIEW

TASK B COALITION MEETING

MAY 4, 1983

DAYTON, OHIO

BY

R. L. DIESSLIN
J. CHURCH

IIT RESEARCH INSTITUTE

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INTRODUCTION TO THE STATE-OF-THE-ART SURVEY

PURPOSE: TO INVESTIGATE THE STATE-OF-THE-ART TECHNOLOGY WHICH SUPPORTS THE FACTORY OF THE FUTURE (FoF)

FOCUS: FACTORY MANAGEMENT LEVEL

SCOPE OF THE SOA SURVEY:

PRIMARY: MOST CURRENT TECHNOLOGY WITH A DEMONSTRATED POTENTIAL FOR COST EFFECTIVENESS

SECONDARY: LEADING EDGE TECHNOLOGY WITH A POTENTIAL FOR DEMONSTRATING COST EFFECTIVENESS BY 1995

EMPHASIS: COMMERCIALLY AVAILABLE TECHNOLOGY

IITRI

CAPTURING THE STATE-OF-THE-ART:

- AIMING AT A MOVING TARGET
- A SNAPSHOT IN TIME

CONSTRAINTS:

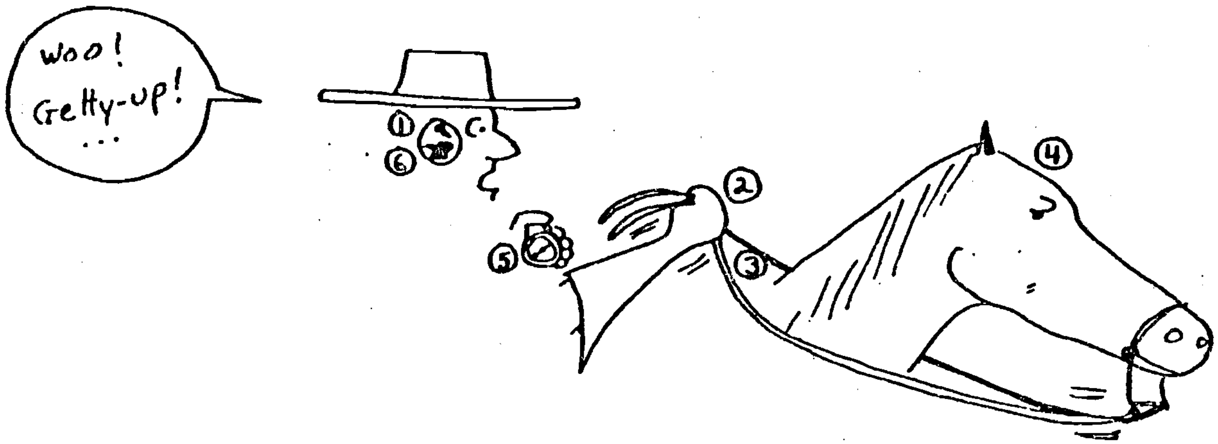
WHILE MANUFACTURING NEEDS MAY REMAIN FOR 20 YEARS (IMPLEMENTATION CONSTRAINED) THE SOA IS CONSTANTLY CHANGING (INNOVATION CONSTRAINED).

IITRI

AVAILABLE TECHNOLOGY

CONTROL IS COMPOSED OF:

1) Plan Work
2) Load Resources
3) Implement Plan
4) Feedback Control Information
5) Measure Performance
6) Take Corrective Action



IITRI

AVAILABLE TECHNOLOGY

INFORMATION/COMMUNICATIONS IS THE UNDERLYING ASPECT OF ALL THAT IS DONE

CONTROL IS A GENERIC ASPECT OF ALL THINGS THAT ARE DONE

THE DESIRE IS TO BE IN CONTROL

3.1

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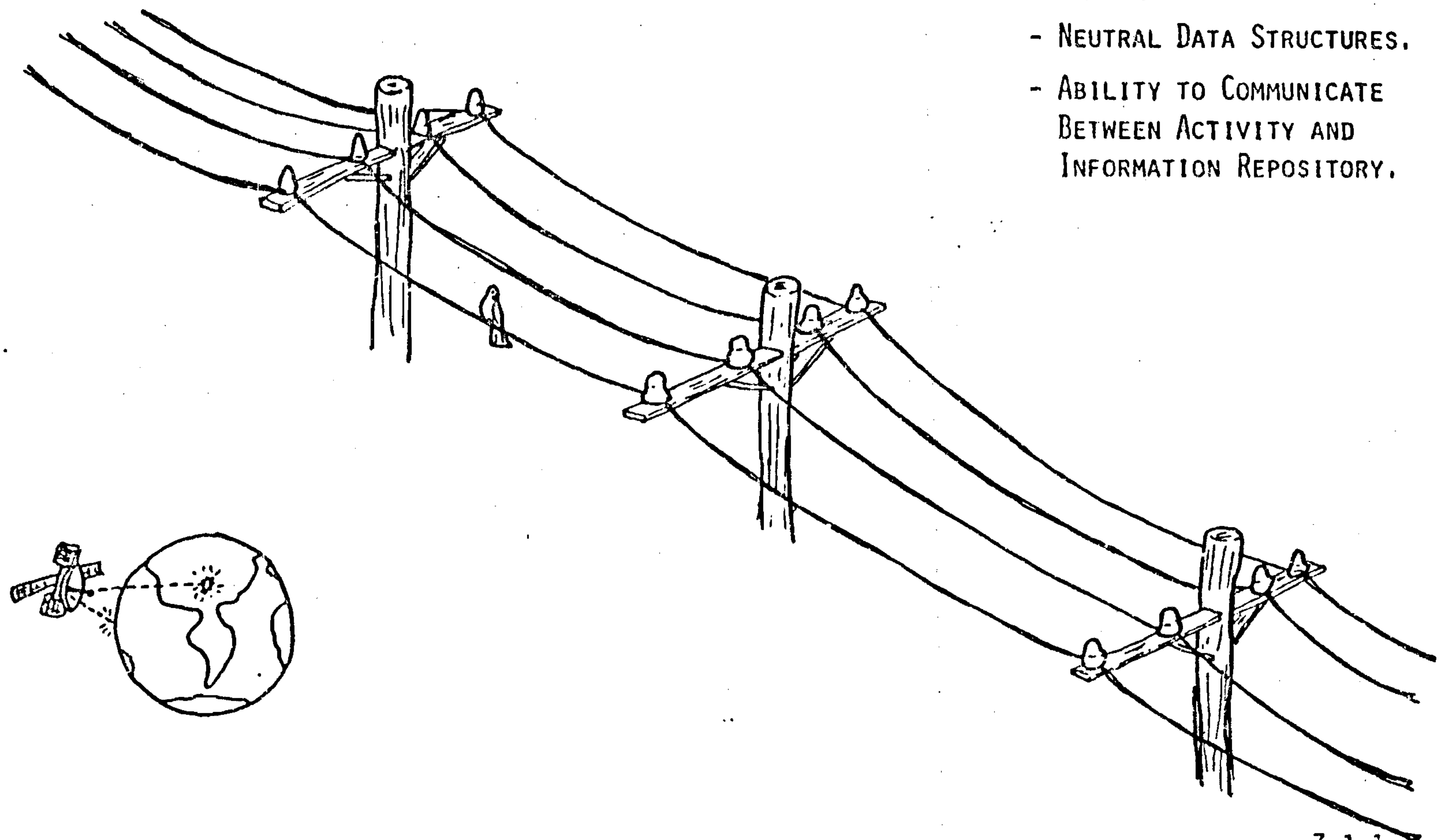
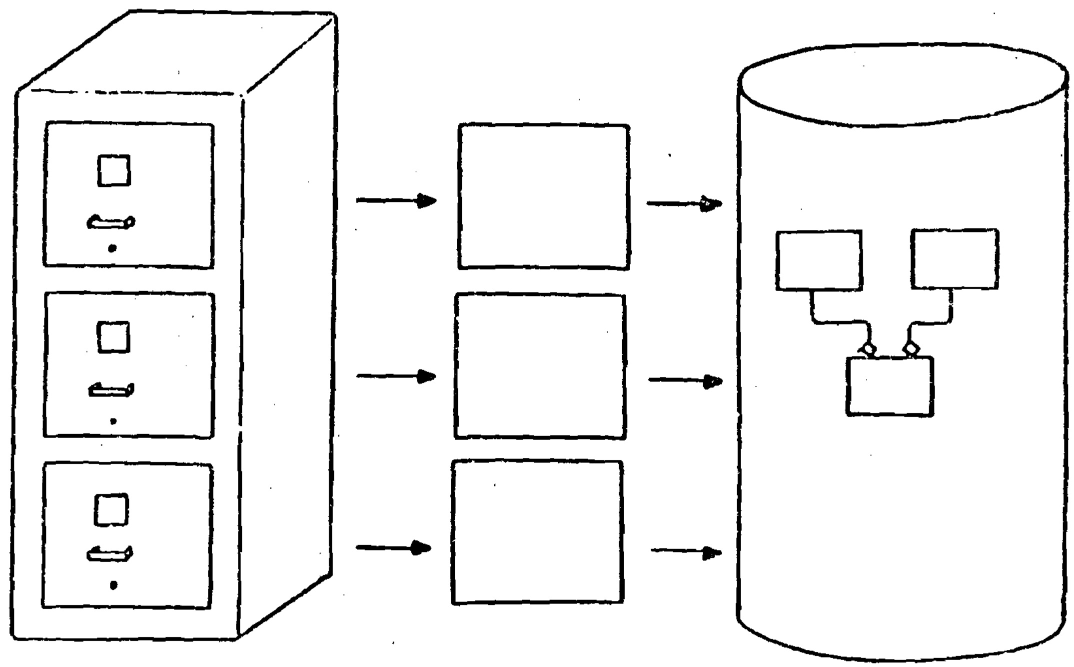
THE GLUE THAT BINDS



CBIS NEEDS:

- NEUTRAL DATA STRUCTURES.
- ABILITY TO COMMUNICATE BETWEEN ACTIVITY AND INFORMATION REPOSITORY.

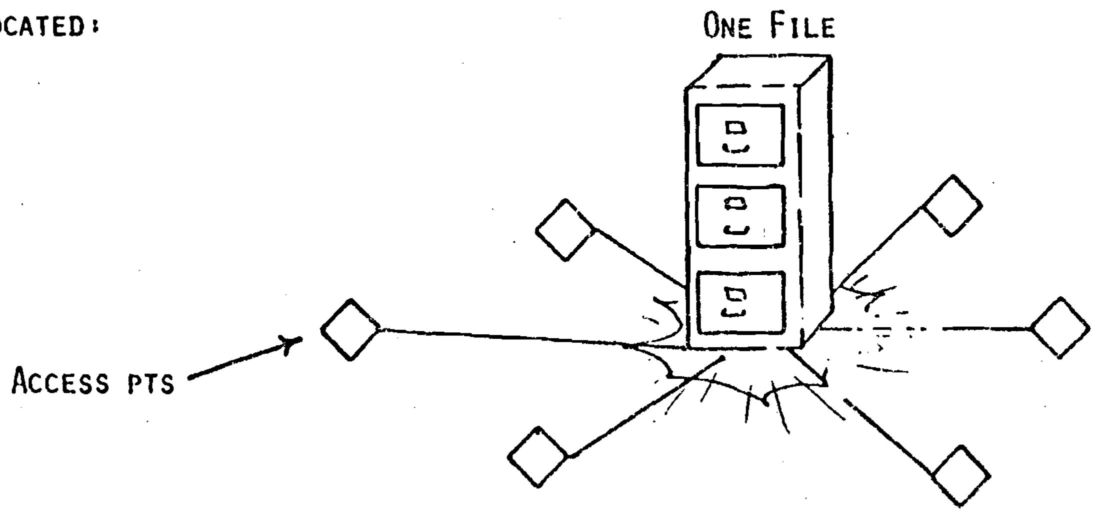
DBMS: SOFTWARE SYSTEMS DEVOTED TO MANAGEMENT OF DATA INTERRELATIONSHIPS



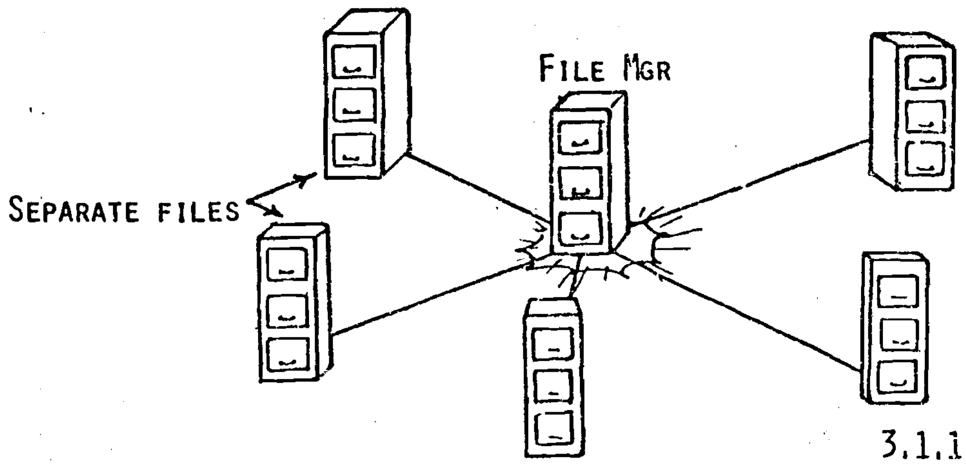
FILE CABINET ENTITY CLASSES COMPUTER DISK

3.1.1.1

1) CENTRALLY LOCATED:



2) DISPERSED:



TYPES OF DBMS SURVEYED:

1) RELATIONAL

2) NETWORKING

INFORMATION FORMAT:

DBMS NAME:
VENDOR:
PRICE:
HARDWARE:
TYPE OF DBMS:
HOST LANGUAGE:
DATA DEFINITION:
DATA ACCESS:
DATA INTEGRITY:
ERROR HANDLING:
SECURITY:
SPECIAL FEATURES:

IITRI

COMPUTER NETWORKS

- PROLIFERATING SINCE MID-TO-LATE 1970's
- MOST COMMON OF THESE HAVE BEEN BASED ON OFF-THE-SHELF HARDWARE
  - USING HARDWIRE LINKS OR TELEPHONE MODEMS
- EARLY VERSIONS BASED ON HIERARCHICAL STRUCTURES
  - USED IN PROCESS CONTROL AND TRANSACTION PROCESSING ENVIRONMENTS
  - SOME COMBINED HIERARCHICAL STRUCTURES WITH BUSES AND LOOPS
- SYSTEMS BASED ON OTHER INTERCONNECT STRUCTURES HAVE EVOLVED TO MEET THE DIVERSITY OF PROCESSING REQUIREMENTS

3.1.1.2

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DBMS: 12 INCLUDED IN SUMMARIES

1) ENCOMPASS
Tanden Computers, Inc.
Relational

2) ORACLE
Relational Software, Inc.
Relational

3) DATACOM/DB
Applied Data Research
Relational

4) NOMAD 2
National CSS
Relational

5) SQL/DS
IBM
Relational

6) INQUIRE and IQ/NET
Infodata Systems, Inc.
Relational

7) PRIME DBMS
Prime Computer, Inc.
Network

8) DM-IV
Honeywell Information Systems, Inc.
Network

9) INGRES
Relational Technology, Inc.
Relational

10) SEED
International Data Base Systems, Inc.
Network

11) TOTAL
CINCOM Systems, Inc.
Network

12) DBMS-10, DBMS-20
Digital Equipment Corp.
CODASYL Network

3.1.1.1

IITRI

DBMS: 12 INCLUDED IN SUMMARIES

1) ENCOMPASS
   TANDEN COMPUTERS, INC.
   RELATIONAL

2) ORACLE
   RELATIONAL SOFTWARE, INC.
   RELATIONAL

3) DATACOM/DB
   APPLIED DATA RESEARCH
   RELATIONAL

4) NOMAD 2
   NATIONAL CSS
   RELATIONAL

5) SQL/DS
   IBM
   RELATIONAL

6) INQUIRE AND IQ/NET
   INFODATA SYSTEMS, INC.
   RELATIONAL

7) PRIME DBMS
   PRIME COMPUTER, INC.
   NETWORK

8) DM-IV
   HONEYWELL INFORMATION SYSTEMS, INC.
   NETWORK

9) INGRES
   RELATIONAL TECHNOLOGY, INC.
   RELATIONAL

10) SEED
   INTERNATIONAL DATA BASE SYSTEMS, INC.
   NETWORK

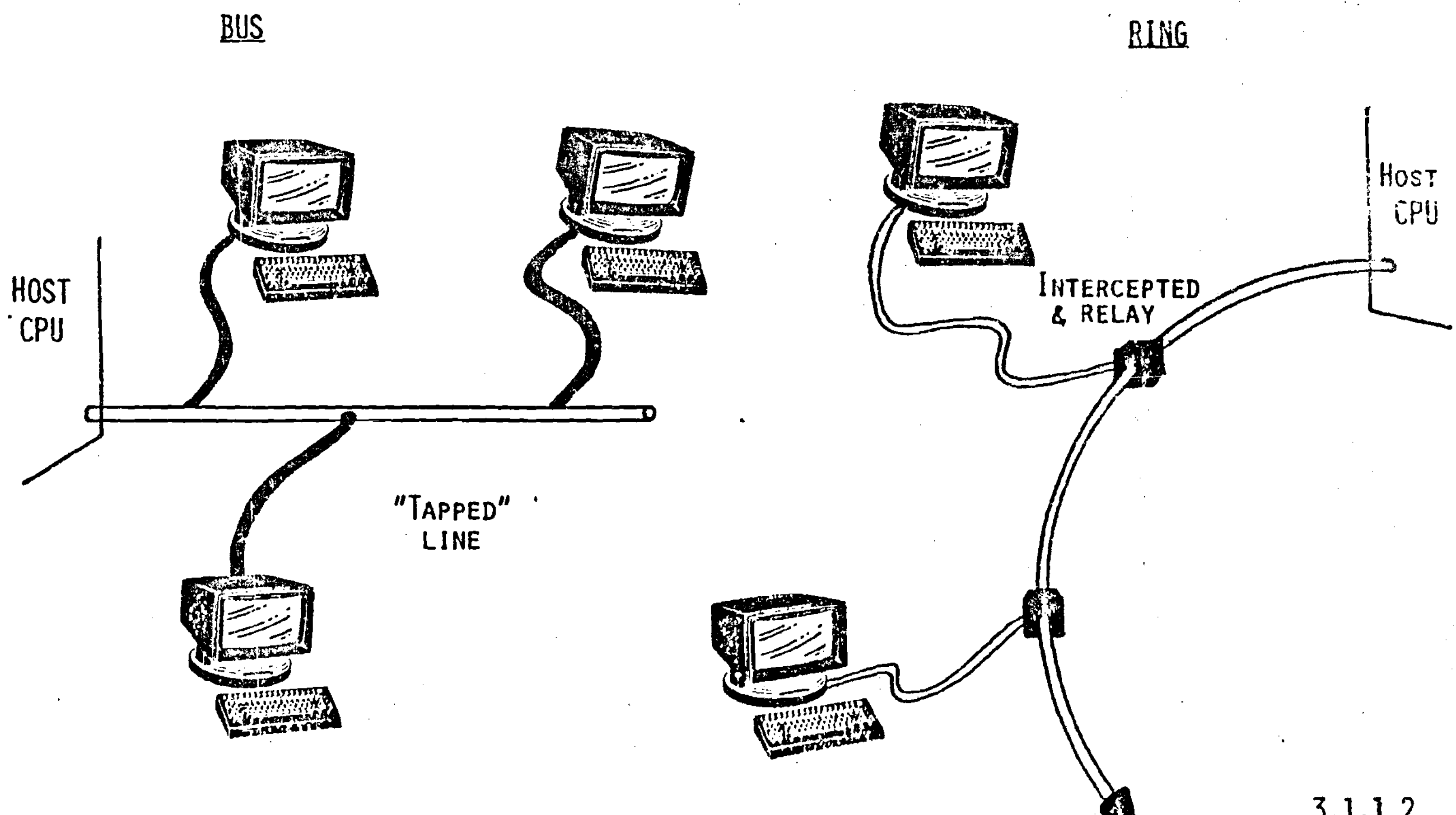
11) TOTAL
   CINCOM SYSTEMS, INC.
   NETWORK

12) DBMS-10, DBMS-20
   DIGITAL EQUIPMENT CORP.
   CODASYL NETWORK

3.1.1.1

A.T./IRM/ COMPUTER NETWORKS

LINKING INFORMATION PHYSICALLY IN THE FACTORY



3.1.1.2

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COMPUTER NETWORKS

THE FOLLOWING MAJOR TECHNOLOGIES ARE PARTICULARLY RELEVANT TO TRENDS IN COMMUNICATION NETWORKS:

- ETHERNET
  - LOCAL AREA NETWORKS AND THEIR INTERCONNECTION
    - > SPEED AND CONNECTION TO OTHER NETWORKS
- HYPERBUS
  - LOCAL AREA NETWORK COMMUNICATION SYSTEM
    - > SPEEDY (BUT EXPENSIVE)
- THE INTELLIGENT CABLE (TIC)
  - > BROAD BAND (FLEXIBILITY)

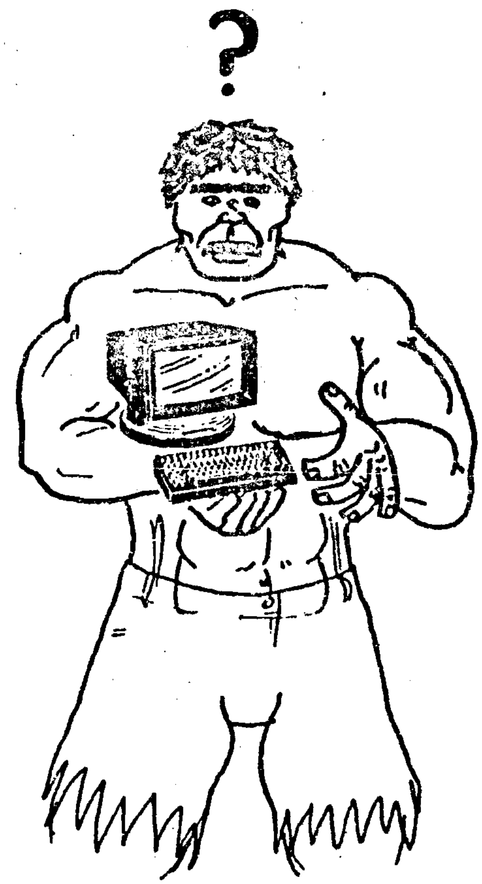
3.1.1.2

TABLE 3-1
Representative Local Area Networks

Name	Vendor/developer	Topology	Access method
Cambridge	Cambridge Univ.	ring	TDMA (token)
Clusterbus	Nestar Sys.	bus	TDMA (CSMA)
Ethernet	Xerox Corp.	bus	TDMA (CSMA/CD)
Flashnet	Ford Aerospace	ring	TDMA (token)
HYPERchannel	Network Sys. Corp.	bus	TDMA (CSMA/CD)
ILLINET	Univ. of Illinois	ring	TDMA (token)
LCS ring	MIT	ring	TDMA (token)
MITRENET	Mitre Corp.	bus	FDM, TDMA (CSMA/CD)
MODWAY	Gould-Modicon	bus	TDMA (token)
Net/One	Ungermann-Bass, Inc.	bus	TDMA (CSMA)
WangNet	Wang Laboratories, Inc.	bus	FDM, TDMA (polled)
Z-NET	Zilog Corp.	bus	TDMA (CSMA/CD)

AT/IRM/ USER INTERFACE

HARDWARE AND SOFTWARE CAPABILITIES TO PROVIDE EASE OF OBTAINING AND SUPPLYING INFORMATION



HARDWARE INTERFACE

- HUMAN INTERACTION
- MACHINE INTERACTION

SOFTWARE INTERFACE

- USER FRIENDLINESS
- HIGH LEVEL LANGUAGE PROLIFERATION

ADVANCING TECHNOLOGY

- 5TH GENERATION COMPUTERS
- ARTIFICIAL INTELLIGENCE
- PARALLEL COMPUTING

3.1.1.3

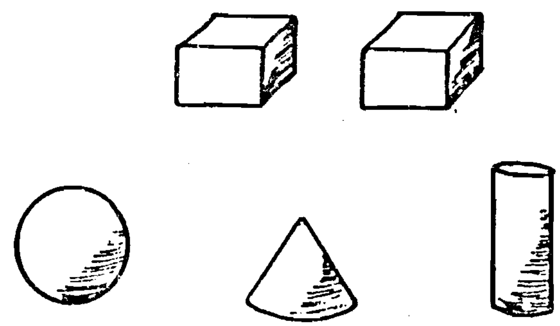
IITRI

AT/IRM/ USER INTERFACE

HARDWARE - HUMAN INTERFACE (WITH CAD):

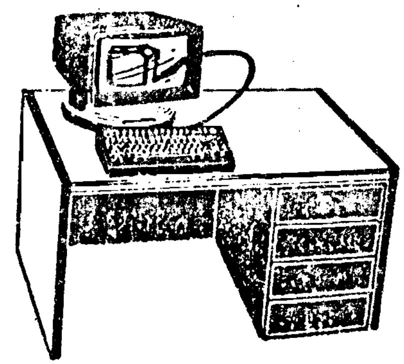
SOLIDS MODELING

BUILDING BLOCK SYSTEMS



BOUNDARY REPRESENTATION

CONSTRUCTIVE SOLID GEOMETRY



RASTER GRAPHICS

3.1.1.3.1.1

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AT/IRM/ USER INTERFACE

HARDWARE - MACHINE:

- o PROGRAMMABLE CONTROLLERS (PC):
  - HAVE KEPT UP WITH TECHNOLOGY
  - SOONER OR LATER EVOLVE TO HIGH-LEVEL LANGUAGE (VS. RELAY-LADDER LANGUAGE)

- o WORK STILL NEEDED:
  - I/O INTERFACE STANDARDS
    PC'S TO TIE INTO DATA BASES

3.1.1.3.1.2

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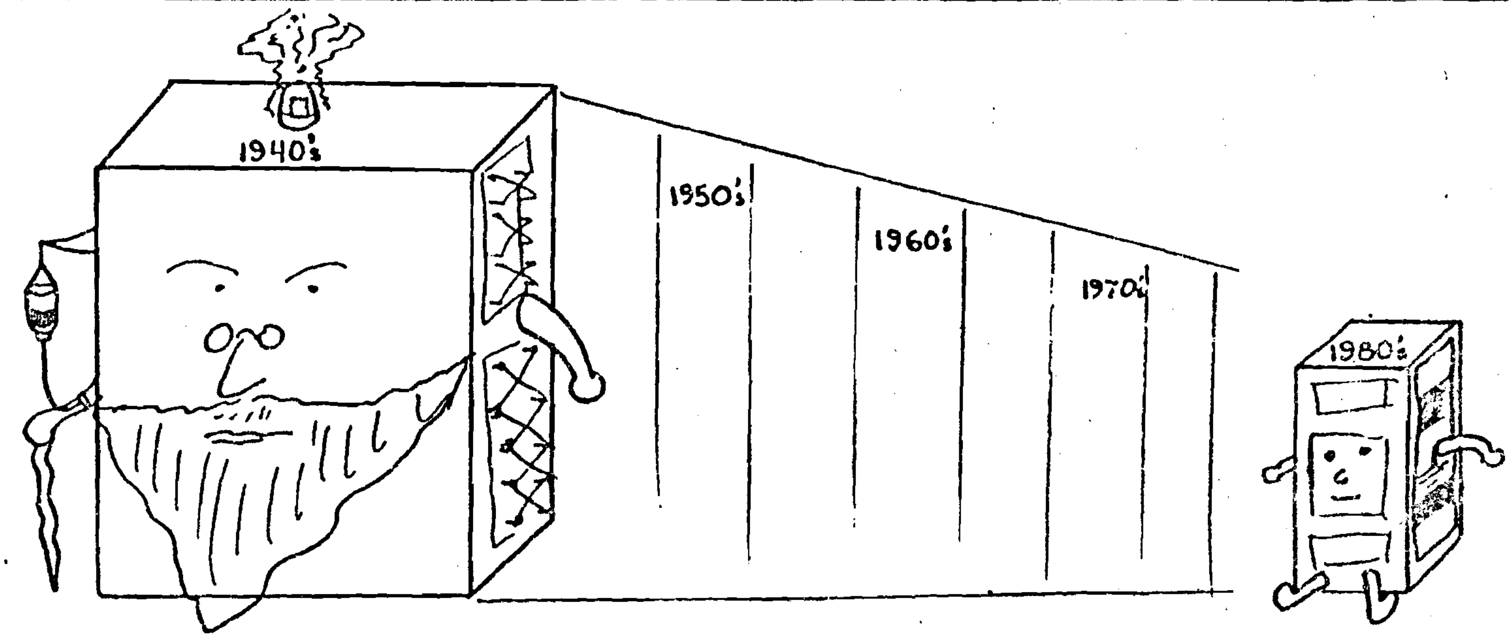
AT/IRM/ ADVANCING TECHNOLOGY



5TH GENERATION COMPUTERS

- Intelligent Interface
- Knowledge-Based Management
- Problem Solving and Inference

3.1.1.4

SOFTWARE INTERFACE:

- o USER FRIENDLY IS NORMATIVE
- o PROLIFERATION OF HIGH-LEVEL LANGUAGES

BASIC	PASCAL
FORTRAN	PL-1
COBOL	ETC.

  - SOFTWARE IS BECOMING PRIME BOTTLENECK IN DEVELOPING COMPUTER SYSTEMS

- o IS ADA THE ANSWER?
  - EVEN IF YES, TOO FAR AWAY TO BE PRACTICAL

- o MEANWHILE, APPLICATION SPECIFIC LANGUAGES HOLD LIMITED PROMISE
  - I.E., VISICAL / MAPPER (UNIVAC) / ADVISE 1100 (PROGRAMMER SUPPORT) / ETC.

ARTIFICIAL INTELLIGENCE:

MIMIC OR SUPPLEMENT HUMAN INTELLIGENCE IN A DECISION-MAKING CONTEXT

1) KNOWLEDGE BASE
   - SET OF INFORMATION (DATA) AND ITS INTERRELATIONSHIPS (DBMS LIKE)

2) INFERENCE PROCEDURE
   - "REASONING"/LEARNING CAPABILITIES
   - HYPOTHESIS MODIFICATION UNTIL APPROACH FOUND THEN TRANSLATED INTO A PROGRAM AND RUN

THE DEFINITION OF AI IS FLUID:

- VISION CAPABILITIES NO LONGER CONSIDERED AI
- VOICE ENTRY BECOMING LESS AND LESS AN AI

IN FACT, THEY ARE NOW BECOMING CONSIDERED AS SOPHISTICATED INPUT MECHANISMS

PARALLEL COMPUTING:

SERIAL COMMUNICATIONS CHANNEL BETWEEN THE CPU AND RAM

THESE MACHINES ARE USUALLY DIVIDED UP INTO:

- MULTIPLE SPECIAL PURPOSE FUNCTIONAL UNITS
- ASSOCIATIVE PROCESSORS (EG. KEY WORDS, ETC)
- ARRAY PROCESSORS
- DATA FLOW PROCESSORS
- END STORAGE PROCESSORS
- DATA BASE PROCESSORS

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AT/IRM/ ADVANCING TECHNOLOGY

ARTIFICIAL INTELLIGENCE (CONTINUED)

NATURAL LANGUAGE SYSTEMS:

- o INTELLECT (AI CORP)
- o PLANES (U.S. NAVY)
- o SRI WORKING A GENERAL PURPOSE SYSTEM

INTELLIGENT OR EXPORT SYSTEMS:

1) PRODUCTION SYSTEMS

   - MODULAR KNOWLEDGE REPRESENTATION SCHEMES
   - BASED ON RULES (CALLED PRODUCTIONS)
   - IN THE FORM OF CONDITION-ACTION PAIRS (IF, THEN = FORMALISM)

2) FRAME-BASED SYSTEMS

   - DECLARATIVE WAY OF RELATIVING FACTS IN NETWORKS I.E., GROUP TECHNOLOGY SYSTEMS (CLASS & CODING)

PROBLEMS WITH PARALLEL STRUCTURES:

- DESIGNING EFFICIENT SOFTWARE IS DIFFICULT
- INTERCONNECTION DEVICES MAY COST MORE THAN THE COMPUTER ITSELF

APPROACHES TO FAST COMPUTING:

1) FAST COMPONENT APPLICATIONS

2) PARALLEL STRUCTURES (E.G., SHARED CPU'S)

   - SUPER COMPUTERS ARE SUPER IN PERFORMANCE AND:

     o COST OF HARDWARE
     o COMPLEXITY

3.1.1.4.2

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APPLICATIONS TECHNOLOGY

DEFINITION: COMMERCIALLY AVAILABLE TECHNOLOGY WHICH ADDRESSES THE SEVEN NEEDS CATEGORIES

LEVEL ONE:

- ICAM SUBSYSTEMS TECHNOLOGIES IDENTIFIED IN PREVIOUS S.O.A. SURVEYS
  - SUMMARIZED IN TERMS OF FoF GENERAL MANAGER LEVEL
  - PROVIDES CONTINUITY AMONG PROJECTS
  - TAKES ADVANTAGE OF PREVIOUS WORK DONE IN ICAM EFFORT
  - ASSISTS IN BINDING SUBSYSTEMS TOGETHER INTO THE FoF CONTEXT

LEVEL TWO:

- INTEGRATED SYSTEMS TECHNOLOGIES
  - A VIEW OF COMMERCIALLY AVAILABLE ATTEMPTS AT TOTAL FACTORY SYSTEMS INTEGRATION
  - KEY TO FoF S.O.A.
  - VIEWED IN TERMS OF FoF MAJOR FUNCTIONAL AREAS

3.1.2

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SUBSYSTEMS TECHNOLOGY

THE SOA OF FACTORY LEVEL MANAGEMENT/INTEGRATION HAS LAGGED CONSIDERABLY BEHIND ADVANCEMENTS MADE IN DISCRETE ELEMENTS OF THE FACTORY STRUCTURE.

- MOST OF THE DISCRETE BUILDING BLOCKS OF THE FoF HAVE BEEN AT LEAST IDENTIFIED, IF NOT DEVELOPED OR MADE COMMERCIALLY AVAILABLE.
- IN COMPARISON, RELATIVELY LITTLE HAS BEEN DONE TO DESIGN AND IMPLEMENT AN INTEGRATED FACTORY LEVEL MANAGEMENT STRUCTURE. THE REASONS ARE STRAIGHTFORWARD:
  - IT IS EASIER TO DEVELOP DISCRETE AREAS FIRST
  - IT IS OVERWHELMING TO CONVERT AN ENTIRE OPERATION
  - IT IS RISKY TO INVEST MASSIVELY IN THE FACE OF ECONOMIC AND MARKET UNCERTAINTIES
  - IT REQUIRES A HIGH LEVEL COMMITMENT

3.1.2

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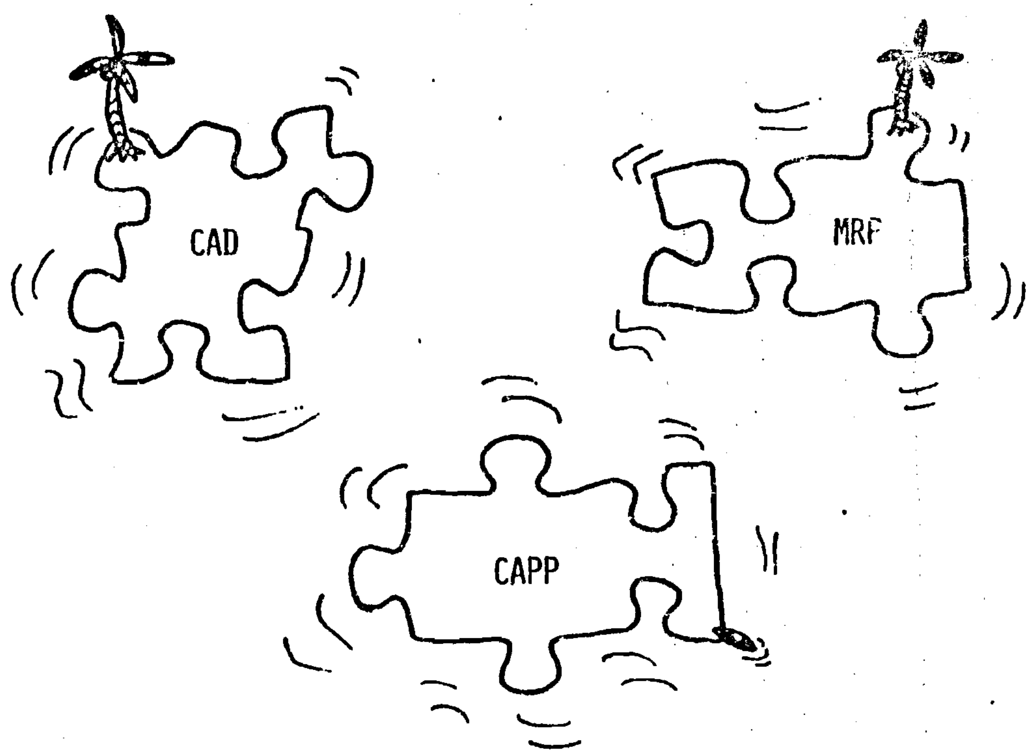
INTEGRATED SYSTEMS TECHNOLOGY

THE ISLANDS:



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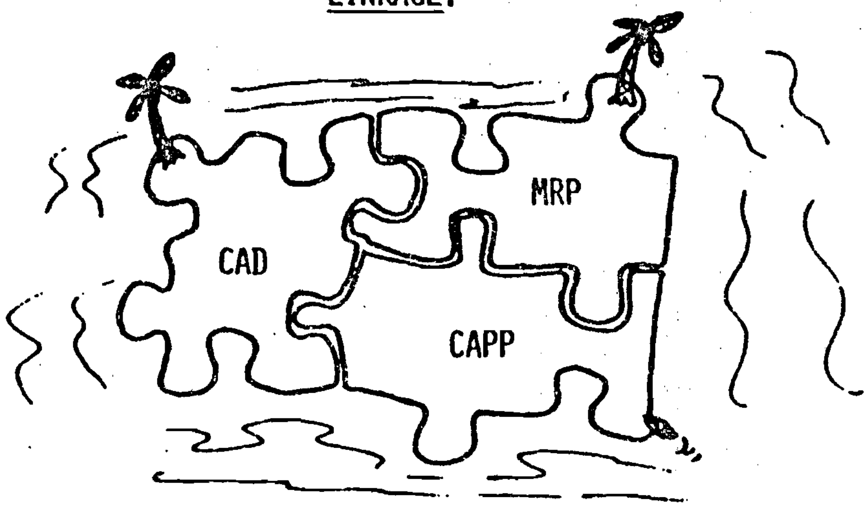

- HEWLETT PACKARD "MANUFACTURER'S PRODUCTIVITY NETWORK"
- G.E. "FACTORY WITH A FUTURE"
- SPERRY UNIVAC "UNIS": AN INTEGRATED CAD/CAM SYSTEM
- OTHERS VIA ACQUISITION, MERGERS AND EXPANSION

IST

KEY DIFFERENCES BETWEEN INTEGRATED VS STAND-ALONE SYSTEMS

- INCREASED ACCESSIBILITY AND SHARING
- INCREASED FLEXIBILITY AND RESPONSIVENESS
- IMPROVED INTEGRITY AND TIMELINESS

3.1.2

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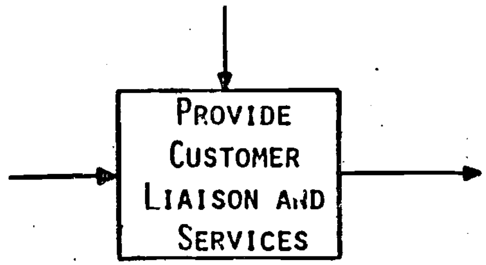
IITRI

I.S.T.: ⟷ PROVIDE CUSTOMER LIAISON (A1)



<u>THE PRIMARY DRIVERS OF GENERIC NEEDS ARE:</u>

- MANAGEMENT AND CONTROL
  - IMPROVED PROPOSALS
  - IMPROVED CONTROL OF MARKETING ACTIVITIES
  - IMPROVED MARKETING SERVICES
- PRODUCT DEFINITION AND PLANNING
  - REDUCE COST AND LEAD TIME FOR MARKETING ACTIVITIES

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IITRI

I.S.T.: A1

STATE OF INTEGRATED SYSTEMS:

- MARKETING MODULES ARE DIRECTED TO HIGH VOLUME COMMERCIAL AND CONSUMER PRODUCT INDUSTRIES
  - RESULT: FEATURES RELATING TO CONTRACT OPERATIONS ARE ABSENT
- MARKETING MODULES HAVE:
  - ORDER TRACKING CAPABILITIES
  - SCHEDULE IMPACT EVALUATION
  - COST AND BILLING FEATURES
- NONE OF THE MARKETING MODULES HAVE:
  - PRODUCT DEFINITION AND PLANNING

3.1.2.1

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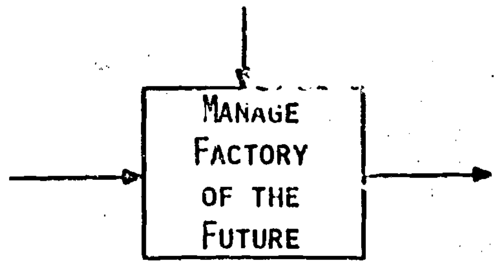
IITRI

I.S.T.: MANAGE FACTORY OF THE FUTURE (A2)



THE PRIMARY DRIVERS OF GENERIC NEEDS ARE:

- MANAGEMENT AND CONTROL
  - IMPROVED TRANSLATION OF STRATEGIC PLANS
  - IMPROVED MANAGEMENT OF RESOURCES AND TIME
  - IMPROVED MANAGEMENT OF TECHNOLOGICAL CHANGE
  - IMPROVED DECISION SUPPORT
- PRODUCT ASSURANCE
- HUMAN RESOURCE MANAGEMENT
- FINANCIAL MANAGEMENT

CORRESPONDING MODULES ARE:

- MASTER SCHEDULING
- CAPACITY PLANNING
- MATERIAL REQUIREMENTS PLANNING
- PRODUCTION CONTROL
  - WORK ORDER SCHEDULING
  - SHOP FLOOR DISPATCHING
  - WORK ORDER TRACKING

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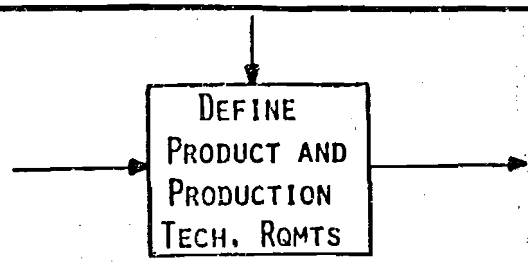
STATE OF INTEGRATED SYSTEMS:

- PRIMARY OBJECTIVE IS TO PROVIDE MANAGEMENT AND CONTROL
  - FEEDBACK CONTROL FUNCTIONS ARE WEAK, BUT PROVISIONS TO GROW
  - NEEDS IN THIS CATEGORY SATISFIED EXCEPT IMPROVED MANAGEMENT OF TECHNOLOGICAL CHANGE
- ONLY ONE SYSTEM ADDRESSES PRODUCT ASSURANCE
  - ENGINEERING ANALYSIS AND ENGINEERING DATA COLLECTION SYSTEM
  - ABILITY TO SELECT, CORRELATE AND REPORT RESULTS ON ACTUAL PROCESS PARAMETERS
  - TRACEABILITY CAN BE MAINTAINED
  - A MODEL SYSTEM
- HUMAN RESOURCE MANAGEMENT; ALL SYSTEMS TO A REASONABLE DEGREE:
  - REDUCE THE NUMBER OF MUNDANE JOBS
  - ENHANCE THE DECISION SKILLS OF PERSONNEL
  - IMPROVE COMMUNICATION
- NO MODULES RELATE TO ORGANIZATION STRUCTURE, MOTIVATION AND SKILL
- ALL SYSTEMS ADDRESS FINANCIAL MANAGEMENT
  - APPROACHES VARY SIGNIFICANTLY

IITRI

I.S.T.: DEFINE PRODUCT AND PRODUCTION TECHNOLOGY REQUIREMENTS (A3)



THE PRIMARY DRIVERS OF GENERIC NEEDS ARE:

- MANAGEMENT AND CONTROL
  - IMPROVED CONTROL OF ENGINEERING ACTIVITIES
- PRODUCT DEFINITION AND PLANNING
  - REDUCED COST AND LEAD TIME FOR ENGINEERING
  - IMPROVED PRODUCT DESIGNS
  - IMPROVED MANUFACTURING PLANS
  - IMPROVED EQUIPMENT AND FACILITIES DESIGN

IITRI

I.S.T.: A3

STATE OF INTEGRATED SYSTEMS:

- ALL SYSTEMS HAVE CAD AND CAE MODULES
  - NO SYSTEM CAN BE USED FOR ALL TYPES OF PRODUCTS
  - LINKS FROM INTEGRATED ENGINEERING TO OPERATIONAL PLANNING AND CONTROL ARE NOT COMPLETE, BUT SOME ARE MOVING IN THAT DIRECTION
- THE SYSTEMS DO PROVIDE IMPROVED CONTROL OF ENGINEERING ACTIVITIES
  - BETTER USE OF PERSONNEL SKILLS
  - MORE EFFICIENT USE OF RESOURCES
  - CLOSER COORDINATION OF ENGINEERING PRIORITIES AND SCHEDULES
- NOT CLEAR THAT THEY PROVIDE MORE CONSISTENCY WITH BUSINESS OBJECTIVES
- THE OBJECTIVE OF THESE MODULES IS TO:
  - REDUCE COST AND LEAD TIME FOR ENGINEERING
  - IMPROVE PRODUCT DESIGN
  - IMPROVE MANUFACTURING PLANS
- EQUIPMENT AND FACILITIES DESIGN IS AN AREA OF WEAKNESS
  - ONLY ONE SYSTEM EVEN ADDRESSES THIS AREA

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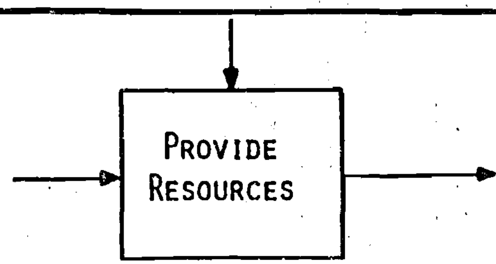
IITRI

I.S.T.: PROVIDE RESOURCES (A4)



THE PRIMARY DRIVERS OF GENERIC NEEDS ARE:

- MANAGEMENT AND CONTROL
  - IMPROVED CONTROL OF PROVISIONING ACTIVITIES
- PRODUCT DEFINITION AND PLANNING
  - IMPROVED FACILITIES, EQUIPMENT AND TOOLS
- HUMAN RESOURCE MANAGEMENT
- MATERIALS MANAGEMENT
  - REDUCE COST AND LEAD TIME FOR PROVISIONING RESOURCES
  - IMPROVE RAW MATERIAL AND PURCHASED COMPONENTS

THE CORRESPONDING MODULES ARE:

- INVENTORY MANAGEMENT
- MATERIAL ISSUES AND RECEIPTS
- PURCHASE ORDER TRACKING

IITRI

I.S.T.: A4

STATE OF INTEGRATED SYSTEMS:

- THE MODULES ARE DESIGNED TO IMPROVE CONTROL OF PROVISIONING ACTIVITIES
- THE MODULES DO NOT ADDRESS
  - THE QUESTION OF IMPROVED FACILITIES, EQUIPMENT AND TOOLS
  - HUMAN RESOURCE MANAGEMENT IN TERMS OF:
    - BETTER RECRUITING OF KEY PERSONNEL
    - BETTER ORIENTATION AND INHOUSE TRAINING
    - BETTER INCENTIVES AND EMPLOYEE MOTIVATION
    - IMPROVED UTILIZATION OF EMPLOYEE SKILLS AND CAREER DEVELOPMENT
- A MAJOR OBJECTIVE OF THE MODULES IS TO REDUCE COST AND LEAD TIME
  - THE APPROACHES TO IMPROVING RAW MATERIAL AND PURCHASED COMPONENTS VARIES CONSIDERABLY
  - SOME HAVE EXTENSIVE VENDOR RATING SYSTEMS

3.1.2.4

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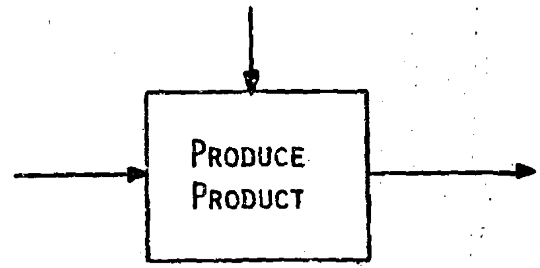
29 June 1984

I.S.T.: PRODUCE PRODUCT (A5)



THE PRIMARY DRIVERS OF GENERIC NEEDS ARE:

- MANAGEMENT AND CONTROL
  - REDUCE COST AND LEAD TIME OF MANUFACTURING ACTIVITIES
  - IMPROVE RESULTS OF MANUFACTURING
  - IMPROVE MANAGEMENT OF MANUFACTURING ACTIVITIES
- PRODUCT DEFINITION AND PLANNING

IITRI

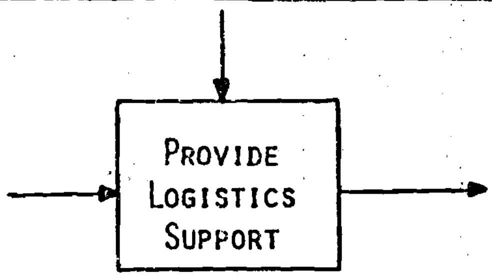
I.S.T.: PRODUCT PRODUCT (A5)

STATE OF INTEGRATED SYSTEMS:

- OPERATION PLANNING AND CONTROL MODULES
  - THE MORE ADVANCED ARE GEARED FOR FACTORY AND PLANT AUTOMATION
- THE MODULES ARE DESIGNED TO REDUCE COST AND LEAD TIME THROUGH:
  - BETTER LOADING
  - BETTER SCHEDULING
  - MONITORING PERFORMANCE
- ONE SYSTEM CAN ANALYZE ENGINEERING AND PRODUCTION DATA
  - SHOULD LEAD TO HIGH QUALITY

3.1.2.5

I.S.T.: PROVIDE LOGISTICS SUPPORT (A6)



THE PRIMARY DRIVERS OF GENERIC NEEDS ARE:

- MANAGEMENT AND CONTROL
  - REDUCE COST AND LEAD TIME
  - IMPROVE CONTROL
- PRODUCT ASSURANCE
  - IMPROVED FIELD SUPPORT

STATE OF INTEGRATED SYSTEMS:

- CONSIDERED A MARKETING FUNCTION FOR CONSUMER AND COMMERCIAL PRODUCTS
- EXISTING MODULES CAN:
  - BE USED TO PREPARE PRODUCT MANUALS
  - FORECAST REPLACEMENT PARTS
  - IMPROVE PRODUCT DESIGN

3.1.2.6

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IITRI | TV

- TECHNOLOGY VOIDS OR TECHNOLOGY AREAS WHICH ARE NOT AVAILABLE TO SUPPORT SUBSYSTEM REQUIREMENTS CAN BE PRIORITIZED IN TERMS OF COST AND PERFORMANCE DRIVERS AND HUMAN FACTORS

- TECHNOLOGY VOIDS AS THEY RELATE TO THE FoF CANNOT BE SO EASILY COMPARTMENTALIZED AND PRIORITIZED

  - THEY CAN BE IDENTIFIED BY NEED CATEGORIES

  - BUT, BECAUSE OF THE INTERACTION BETWEEN NEEDS, AND OFTEN LONG-RANGE IMPLICATIONS, IT IS NOT POSSIBLE TO MEASURE THE IMPACT OF FULFILLING THE INDIVIDUAL NEEDS

IITRI

TV: INFORMATION RESOURCE MANAGEMENT NEEDS CATEGORY

THE BASIC INFORMATION NEEDS ARE:

- A MECHANISM FOR INTEGRATION
- PROVISIONS FOR DISTRIBUTED DATABASES (ON DISTRIBUTED MACHINES)
- FLEXIBILITY TO THE END USERS
- REDUCTION OF THE NEED FOR SOFTWARE
- IMPLEMENTATION PLAN WHICH WILL:
  - MINIMIZE INITIAL IMPACT
  - BE ABLE TO EVOLVE

THE VOIDS ARE:

- PROCEDURE FOR CONVERTING A PROLIFERATION OF INDEPENDENT DATABASES INTO AN INTEGRAL SYSTEM
- HARDWARE AND SOFTWARE PROTOCOL STANDARDS (SEMI)
- COMPATIBLE HARDWARE
- CUSTOMIZABLE SYSTEMS
- COMMERCIALLY AVAILABLE TECHNOLOGY FOR IMPLEMENTATION

3.2.1

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29 June 1984

IITRI

TV: FACTORY MANAGEMENT NEEDS CATEGORY

BASIC CONTROL NEEDS ARE:

- TRUELY CLOSED-LOOP SYSTEMS
- TIMELY-ACCURATELY-READILY AVAILABLE CONTROL INFORMATION FOR DECISION SUPPORT
- IMPROVED LEVEL OF CONTROL SYSTEM RESPONSE TO CHANGE
- IMPROVED TOOLS FOR DECISION SUPPORT

BASIC VOIDS ARE:

- COMPATIBLE MECHANISMS FOR DATA COLLECTION
- REAL TIME DATA COLLECTION
- HARDWARE AND SOFTWARE SUPPORT FOR DATA COLLECTION

3.2.2

TV: PRODUCT DEFINITION AND PLANNING NEEDS CATEGORY

- PRODUCT DEFINITION AND PLANNING INVOLVES SEVERAL DISCIPLINES (E.G., INTERATIVE GRAPHICS, FINITE ELEMENT MODELING, SIMULATION)
- A NEED FOR ALL DISCIPLINES TO BE NETWORKED ON A COMMON OPERATING SYSTEM
- ADVANCES IN OTHER INDUSTRIES MAY OR MAY NOT APPLY TO A MODERN, HIGHLY COMPLEX AEROSPACE PROGRAM WITH THE VAST AMOUNT OF DETAIL AND CHANGE ACTIVITY
- THE GREATEST BARRIER TO IMPLEMENTATION IS THE ORGANIZATIONAL IMPACT

3.2.3

IITRI

TV: PRODUCT ASSURANCE NEEDS CATEGORY

BASIC ASSURANCE NEEDS ARE:

- IMPROVED ORGANIZATION INTERFACE DURING NEW PRODUCT INTRODUCTION
- IMPROVED QUALITY INFORMATION SYSTEM
- EFFECTIVE QA/QC FIELD INFORMATION, ACQUISITION AND UTILIZATION
- NEW WAYS OF TEST AND INSPECTION
- SOFTWARE QUALITY ASSURANCE

BASIC VOIDS ARE:

- EFFECTIVE MECHANISM OR NETWORK BY WHICH INFORMATION CAN BE COLLECTED AND COMMUNICATED
- EFFECTIVE HISTORICAL DATABASE
- "IN-LINE" QA/QC FUNCTIONS
- SOFTWARE QUALITY ASSURANCE METHODS

3.2.4

TV: HUMAN RESOURCE MANAGEMENT NEEDS CATEGORY

BASIC NEEDS CENTER AROUND:

- SKILL REQUIREMENTS
- INFORMATION NEEDS
- PRODUCT VS. PROCESS "FOCUS"
- INVOLVEMENT
- ORGANIZATION STRUCTURE
- MOTIVATION
- BETTER AND LONGER-TERM PLANNING
- ORGANIZATIONAL DEVELOPMENT

NEEDS ADDRESSED:

- REDUCTION OF MUNDANE JOBS
- ENHANCING DECISION SKILLS
- IMPROVED COMMUNICATION

TV: FINANCIAL MANAGEMENT NEEDS CATEGORY

BASIC FINANCIAL NEEDS ARE:

- A NEW METHOD OF ACCOUNTING
- A CONSOLIDATION AND STANDARDIZATION OF FINANCIAL DATABASES
- AUTOMATIC PART AND RESOURCE COST COLLECTION
- IMPROVED MEASURES OF PERFORMANCE/PRODUCTIVITY
- REDUCED INVENTORY COSTS
- IMPROVED METHODS OF PRODUCING AND PRESENTING FINANCIAL INFORMATION
- FINANCIAL SYSTEMS INTEGRATION WITH PRODUCTION CONTROL SYSTEMS
- TOOLS FOR MORE ACCURATE BUDGETING
- IMPROVED SYSTEMS FOR GENERATING ACCURATE MANUFACTURING COSTS FOR PARTS AND WHOLE SYSTEMS (AND LINK TO ENGINEERING TRADE-OFF STUDIES)
- FORECASTING MODEL(S)
- IMPROVED TOOLS FOR EVALUATING ROI/ROA

TV: MATERIALS MANAGEMENT NEEDS CATEGORY

BASIC MATERIAL MANAGEMENT NEEDS:

- IMPROVE COMMUNICATION WITH SUBCONTRACTORS
- REDUCTION IN MATERIAL COSTS
- IMPROVED WORK-IN-PROGRESS MANAGEMENT
- MORE EFFECTIVE FACILITIES AND EQUIPMENT MANAGEMENT

BASIC VOIDS ARE:

- NOT IN THE TECHNOLOGY BUT IN THE APPLICATION OF WHAT IS AVAILABLE
- THE INCENTIVE TO IMPROVE THIS AREA

3.2.6

FTR110510000U
29 June 1984

APPENDIX B

DOCUMENT REQUEST FORMS

ICAM CONCEPTUAL DESIGN FOR
COMPUTER INTEGRATED MANUFACTURING

DOCUMENT REQUEST ORDER FORM

SUBMIT DOCUMENT REQUESTS TO: AFWAL/MLTC
ICAM Program Library
Wright Patterson AFB OH 45433

VOLUME NUMBER AND MANAGEMENT NUMBER	TITLE OF DOCUMENT	CHECK (✓)
AFWAL-TR-84-4020, Vol. 1,	OVERVIEW	( )
AFWAL-TR-84-4020, Vol. 2,	FACTORY OF THE FUTURE, PARTS 1-6	( )
AFWAL-TR-84-4020, Vol. 3,	INTEGRATED COMPOSITES CENTER, PARTS 1-10	( )
AFWAL-TR-84-4020, Vol. 4,	QUALITY ASSURANCE MODELING, PARTS 1-6	( )
AFWAL-TR-84-4020, Vol. 5,	BENEFITS TRACKING, TECHNOLOGY TRANSFER	( )
AFWAL-TR-84-4020, Vol. 6,	RECOMMENDATIONS FOR FUTURE PROJECTS	( )

PLEASE PRINT

NAME: ______ MAIL CODE: ______

TITLE: ______

DEPARTMENT: ______

COMPANY: ______

STREET or P. O. BOX: ______

CITY: ______ STATE: ______ ZIP: ______

REQUIREMENT FOR DOCUMENT

Document(s) requested for the purpose of (intended use and program/project application must be provided):

______

______

Documents generated under the contract contain controlled distribution and export control clauses.

I am a U.S. citizen. I am employed by a U.S. organization/company and am aware that the use of these Air Force documents must comply with:

U.S. EXPORT CONTROL LAWS

This document contains information for manufacturing or using munitions of ware Export of the information contained herein or release to foreign nations within the United States without first obtaining an export license is a violation of the International Traffic in Arms Regulations. Such violation is subject to a penalty of up to 2 years imprisonment and a fine of $100,000 under 22 USC 2778.

Signature: ______ ***Date:*** ______

Telephone No.: ______

FACTORY OF THE FUTURE CONCEPTUAL FRAMEWORK

DOCUMENT REQUEST ORDER FORM

SUBMIT DOCUMENT REQUESTS TO: AFWAL/MLTC
ICAM Program Library
Wright-Patterson AFB OH 45433

VOLUME NUMBER AND MANAGEMENT NUMBER	TITLE OF DOCUMENT	CHECK (✓)
SD 110512000	Scoping Document	( )
NA01.?512000	Needs Analysis Document	( )
SAD110512000	State-of-the-Art Document	( )
SRD110512000	System Requirements Document	( )
SS 110512000	System Specification Document	( )
MMR110512000	Conceptual Framework Document	( )

PLEASE PRINT

NAME: ______________________ MAIL CODE: __________

TITLE: ______________________

DEPARTMENT: ______________________

COMPANY: ______________________

STREET or P. O. BOX: ______________________

CITY: ______________ STATE: ______ ZIP: ______

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Signature: ______________________ ***Date:*** __________

Telephone No.: ______________________

INTEGRATED COMPOSITES CENTER

DOCUMENT REQUEST ORDER FORM

SUBMIT DOCUMENT REQUESTS TO: AFWAL/MLTC
ICAM Program Library
Wright-Patterson AFB OH 45433

VOLUME NUMBER AND MANAGEMENT NUMBER	TITLE OF DOCUMENT	CHECK (✓)
SD 110511000	Scoping Document	( )
NAD110511000	Needs Analysis Document	( )
SED110511000	System Environment Document	( )
SAD110511000	State-of-the-Art Document	( )
SRD110511000	System Requirements Document	( )
SS 110511000	System Specification Document	( )
SDS110511000	System Design Specification Document	( )
DS 110511000	Development Specification Document	( )
STP110511000	System Test Plan Strategy	( )
IP 110511000	Implementation Plan Strategy	( )

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NAME: ____________________ MAIL CODE: ____________

TITLE: ____________________

DEPARTMENT: ____________________

COMPANY: ____________________

STREET or P. O. BOX: ____________________

CITY: ____________ STATE: ____________ ZIP: ____________

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Signature: ____________________ ***Date:*** ____________

Telephone No.: ____________________

QUALITY ASSURANCE MODELING AND ANALYSIS

DOCUMENT REQUEST ORDER FORM

SUBMIT DOCUMENT REQUESTS TO: AFWAL/MLTC
ICAM Program Library
Wright-Patterson AFB OH 45433

VOLUME NUMBER AND MANAGEMENT NUMBER	TITLE OF DOCUMENT	CHECK (✓)
SD 110513000	Scoping Document	( )
NAD110513000	Needs Analysis Document	( )
SED110513000	System Environment Document	( )
SRD110513000	System Requirements Document	( )
TTD110513000	Architecture for Product Assurance	( )
ISP110513000	QA Program Management Standard Recommendations	( )

PLEASE PRINT

NAME: ____________________ MAIL CODE: __________

TITLE: ____________________

DEPARTMENT: ____________________

COMPANY: ____________________

STREET or P. O. BOX: ____________________

CITY: __________ STATE: __________ ZIP: __________

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Signature: ____________________ ***Date:*** __________

Telephone No.: ____________________

*USGPO:1984-759-062-1061